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WATER AND LIFE.

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It was assuredly not chance that led Thales to found philosophy and science with the assertion that water is the origin of all things. Whether his belief was most influenced by the wetness of animal tissues and fluids, or by early poetic cosmogonies, or by the ever-present importance of the sea to the Ionians, however vague his conception of water may, indeed must, have been, he at least expressed a conclusion which proceeded from experience and serious reflection. Later, when positive knowledge had already grown to be a substantial basis for speculation, both meteorological and chemical views contributed to Aristotle's decision to include water among his elements. And it is especially worthy of note that of earth, air, fire, and water, the last is the only one which happens to be an individual chemical compound. From that day to this the unique position of water has never been shaken. It remains the most familiar and the most important of all things.

Within a comparatively recent time, to be sure, it has definitely lost its claims as a true element, in the modern sense, but meanwhile almost every great development of science has but contributed to make its importance more clear. In physics, in chemistry, in geology, in meteorology, and in biology nothing else

threatens its preëminence. The physicist has perforce chosen it to define his standards of density, of heat capacity, etc., and as a means to obtain fixed points in thermometry. The chemist has often been almost exclusively concerned with reactions which take place in aqueous solution, and the unique chemical properties of water are of fundamental significance in most of the departments of his science. In geology Neptunism has at length won a certain though incomplete triumph over Plutonism, and the action of water now appears to be far the most momentous factor in geological evolution. The meteorologist perceives that the incomparable mobility of water, which depends upon its peculiar physical properties and upon its existence in vast quantities in all three states of solid, liquid, and gas, is the chief factor among the properties of matter to determine the nature of the phenomena which he studies; and the physiologist has found that water is invariably the principal constituent of active living organisms. Water is ingested in greater amounts than all other substances combined, and it is no less the chief excretion. It is the vehicle of the principal foods and excretory products, for most of these are dissolved as they enter or leave the body. Indeed, as clearer ideas of the physico-chemical organization of protoplasm have developed, it has become evident that the organism itself is essentially an aqueous solution in which are spread out colloidal substances of vast complexity. As a result of these conditions, there is hardly a physiological process in which water is not of fundamental importance.

All of these circumstances, which completely justify the interest in water which Thales and Aristotle, and nearly all later students of nature have manifested, depend in great part upon the quantity of water which is present outside the earth's crust, and upon its often unique physical and chemical properties. Doubtless if it were not for the enormous quantity of water which exists upon our planet, all its physical properties would be of little avail to bring about its universal importance in nature.

Of the total extent of the earth's surface, the oceans make up about three fourths, and they contain an amount of water sufficient if the earth were a perfect sphere to cover the whole area to a depth of between two and three miles. This corresponds to about 0.2

per cent. of the volume of the globe. The occurrence of water is moreover not less important and hardly less general upon the land. In addition to lakes and streams, water is almost everywhere present in large quantities in the soil, retained there mainly by capillary action, and often at greater depths. The atmosphere also contains an abundance of water as aqueous vapor and as clouds. Now the very occurrence of water upon the earth and especially its permanent presence is due in no small degree to its chemical stability in the existing physical and chemical conditions. This stability is of great moment in the various inorganic and organic processes in which water plays so large a part. In the first place, the chemical reactions in which it is concerned during the process of geological evolution, though they are no doubt in the total of great magnitudes, are both slow and far from violent. Long since any very active changes of this sort, so far as the superficial part of the crust is concerned, have run their course. In the second place, water is really, at the temperature of the earth, and in comparison with most other chemical substances, an extremely inert body, for the union of hydrogen with oxygen is so firm that it is not readily dissolved.

Thus water exists as a singularly inert constituent of the atmosphere, as a liquid nearly inactive in chemical processes on the surface and in the soil, and everywhere as a mild solvent which does not easily attack the substances which in great variety dissolve in it. The chemical changes which do follow upon solution are not such as to produce substantial chemical transformations, and most substances can pass through water unscathed. The nature of water, then, is a great factor in the chemical stability which no less than the physical stability of the environment is essential to the living mechanism.

Thermal Properties.

These characteristics were recognized at an early stage in the development of modern science, and in many cases their special importance in meteorology and in other departments of the sciences of nature is almost self-evident.

Specific Heat.

First among these is the heat capacity, or as it is more commonly termed, the specific heat of water. This quantity has the value of 1.000 for the interval between 0° and 1° cent., a number which is due to the choice of water in defining the calorie or fundamental unit of heat.

It is unnecessary to enter upon an elaborate analysis of the data concerning specific heats, for the magnitude of the specific heat of a substance is dependent upon its chemical nature, as was first made clear by Dulong and Petit in 1819. The law which bears their name consists of the statement that in the case of elementary substances the product of specific heat and atomic weight is a constant, — roughly, 6.4. Certainly this so-called law is a mere approximation, and some elements, notably carbon, silicon, and boron, at the ordinary temperature depart widely from its requirements, but in the main the approximation holds good. Later the researches of Neumann, Garnier, Cannizaro, and especially of Kopp, made possible an extension of the law to compounds.

It is evident that the law of Dulong and Petit amounts to the statement that for all elementary substances the quantity of heat which is required to change the temperature of every atom, regardless of its nature, is a constant. So it is that the conclusion is warranted that water shares the characteristic of very high specific heat with a very small number of substances, among which hydrogen and ammonia are probably the only important chemical individuals. From this conclusion another follows directly, namely, that water possesses certain nearly unique qualifications which are largely responsible for making the earth habitable or at least very favorable as a habitation for living organisms. It need hardly be pointed out that this importance of the high heat capacity of water is a very well-known fact. Even in the early decades of the nineteenth century, when natural theology and arguments from design were the subject of lively controversy, especially in England, such subjects were very familiar, and an excellent temperate discussion from the theologian's side will be found in Whewell's Bridgewater Treatise. At that time, before a

clear formulation of the concept of adaptation existed, it was of course impossible to disentangle such natural fitness from the results of the organic evolutionary process. In the more modern period since the publication of "The Origin of Species," the late Prof. J. P. Cooke of Harvard has dwelt upon this and other properties of water. He too endeavored to employ such facts as theological arguments, but in spite of many sound contentions with less success in a more skeptical age.

The most obvious effect of the high specific heat of water is the tendency of the ocean and of all lakes and streams to maintain a nearly constant temperature. This phenomenon is of course not due alone to the high specific heat of water, being also dependent upon evaporation, freezing, and a variety of circumstances which automatically mix and stir water. But in the long run the effect of high specific heat is of primary importance.

A second effect of the high specific heat of water is the moderation of both summer and winter temperatures of the earth. It is not easy to estimate the total magnitude of this effect, but the manner in which it comes about is well illustrated by the differences between seaboard and inland climates or between the climate of a large part of the United States, which is a continental climate, and that of Western Europe, which is essentially an insular climate. In the most extreme form such moderation of climate is to be observed on the high seas and upon small islands. There are found the smallest known differences between the mean temperature of different months of the year and of different hours of the day and the least tendency to violent changes of temperature. The calculation of Zenker regarding normal temperatures may be cited as a good illustration of the nature of the case. (See page 6.)

The high heat capacity of water operates in still another manner to regulate temperature upon the land and at the same time to increase the mobility of the environment of marine organisms. For directly or indirectly it is involved in the formation and duration of ocean currents, especially the movement of water in the depths from the polar to the tropical seas, and it determines the amount of heat carried by such currents. A similar and even more important "function" is the direct promotion of winds,

with the resulting distribution of aqueous vapor throughout the atmosphere, a primary factor in the dissemination of water by means of the rainfall. Here the essential thing is the existence of a warm reservoir in the tropics and of two similar cold reservoirs at the poles. Under these circumstances the circulation of winds, bearing away water vapor from the tropical oceans, is inevitable, and the process is intensified by the high specific heat of water.

NORMAL TEMPERATURES. CENT.

Latitude.	Continental Climate.	Marine Climate.	Difference
0°	34.6	26.1	−8.5
10	33.5	25.3	−8.2
20	30.0	22.7	−7.3
30	24.1	18.8	−5.3
40	15.7	13.4	−2.3
50	5.0	7.1	2.1
60	−7.7	0.3	8.0
70	−19.0	−5.2	13.8
80	−24.9	−9.2	16.7
90	−26.1	−8.7	17.4

The living organism itself is directly favored by this same property of its principal constituent, because a given quantity of heat produces as little change as possible in the temperature of its body. Man is an excellent case in point. An adult weighing 75 kg. (165 lb.) when at rest produces daily about 2 400 great calories, which is an amount of heat actually sufficient to raise the temperature of his body more than 32 degrees cent. But if the heat capacity of his body corresponded to that of most substances, the same quantity of heat would be sufficient to raise his temperature between 100 degrees and 150 degrees. In these conditions the elimination of heat would become a matter of far greater difficulty, and the accurate regulation of the temperature of the interior portion of his body, especially during periods of great muscular activity, well-nigh impossible. Extreme constancy of the body temperature is of course a matter of vital importance,

at least for all highly organized beings, and it is hardly conceivable that it should be otherwise. In the first place, marked influence of change of temperature upon chemical reaction is almost universal, and as a rule an increase of 10 degrees cent. in temperature will more than double the rate of a chemical change. Secondly, all living organisms contain both chemical substances and physico-chemical structures or systems which begin to be altered and usually irreversibly altered, at a temperature which is very little above that of the human body. It is perhaps imaginable that conditions might be otherwise in beings of a very different kind, but to-day every chemist well knows that if he is to control a chemical process, almost the first desideratum is rigid regulation of the temperature at which the process takes place.

It is therefore incontestable that the unusually high specific heat of water tends automatically and in most marked degree to regulate the temperature of the whole environment, of both air and water, land and sea, and that of the living organism itself. Likewise the same property favors the circulation of water by facilitating the production of winds, beside contributing to the formation of ocean currents. Here is a striking instance of natural fitness which in like degree is unattainable with any other substance except ammonia.

Latent Heat.

Very different from specific heat in their relationship to the chemical constitution of a substance, but not unlike it in biological importance, are the so-called latent heats of melting and of evaporation. The latent heat of melting is expressed as the number of calories which are required to convert one gram of solid at the freezing point into one gram of liquid at the same temperature. For water its value is approximately 80, which indicates that the same quantity of heat must be employed to melt ice as to raise the temperature of the resulting ice-water to 80 degrees cent.

The latent heat of evaporation is similarly defined as the number of calories required to change one gram of liquid into vapor. Its magnitude depends upon the temperature at which the process

takes place. The latent heat of evaporation of water is approximately 536. There is required, accordingly, as much heat to boil away one gram of water as to raise the temperature of 536 grams through 1 degree cent.

There are a number of important effects of the high latent heats of fusion and evaporation of water upon the meteorological processes. When, for example, a body of water becomes cooled to its freezing point, the further abstraction of heat cannot lower its temperature below that point, which to be sure is somewhat variable in the case of salt water. And so long as water and ice exist in contact, the system constitutes a thermostat, a very accurate one if the water be fresh, which changes only in respect to the quantities of ice and water as heat is added or removed. Heating serves merely to melt the ice, cooling to freeze the water. Accordingly as long as the earth shall remain habitable, the cooling of its oceans and seas will remain rigidly limited by their freezing point. However inclement the atmosphere, the ocean can always support life until the final extinction of water by cold.

It is worthy of note that the freezing point of water, though to man with his carefully regulated body-temperature apparently low, is in reality very high indeed compared with that of any like substances, — perhaps 100 degrees cent. above the average.

TABLE OF MELTING POINTS.

		Degrees Cent.
Water	H_2O	0.0
Hydride of antimony	SbH_3	−91.5
Hydride of arsenic	AsH_3	−113.5
Hydrobromic acid	HBr	−87
Hydrochloric acid	HCl	−112.5
Hydrofluoric acid	HF	−92.3
Hydriodic acid	HI	−50
Methane	CH_4	−185.8
Carbon dioxide	CO_2	−57
Hydride of phosphorus	PH_3	−132.5
Hydrogen sulphide	H_2S	−85.6
Sulphurous oxide	SO_2	−76
Ammonia	NH_3	−75
Nitric oxide	NO	−167

This is, no doubt, one of the most important facts with which we are concerned, for while a very large number of chemical processes take place quite freely at 0° the conditions are very different at the freezing point of ammonia for instance. At that temperature the velocity of most chemical processes is but a fraction of one per cent. of their velocity at 0°, and a large part of the chemical activity which is familiar to us ceases.

The result of the unusually high freezing point of water and of the phenomena of latent heat is felt, however, not merely in the avoidance of an excessive fall in the temperature of lakes and seas. As above explained, whenever the ocean comes in contact with climates of very low temperature it tends to moderate them, the more effectively the greater the disparity between the temperature of the air and that of the water, and here latent heat is quite as important a factor, though indirectly, as specific heat.

It remains to point out that the latent heat of melting of water is nearly the greatest which has yet been discovered, being exceeded in fact by that of ammonia alone.

Accordingly, the processes above described possess nearly the highest possible efficiency. A very large amount of heat must be abstracted from a body of water before it can be solidified; after a given amount of cooling a very large quantity of water must remain liquid; a body of water at 0° cent. can warm up a very large amount of colder air with the formation of a very small quantity of ice. Thus the permanency of the ocean, and the moderating effect of water upon cold climates are very nearly maximal. These are also facts, directly dependent upon the physico-chemical nature of water, which are remarkably favorable to the organism.

Still more important is the latent heat of evaporation of water. Wherever water is in contact with the air, evaporation must take place, until, if the system be of small dimensions, equilibrium is established between aqueous vapor and the liquid, in short, until the air is saturated with water. Unlike freezing, which occurs only at one particular temperature, this process goes on continuously throughout all ranges of temperature at which liquid water can exist, and even upon ice at low temperatures. It is always accompanied by the conversion of heat in the amount measured

by the latent heat of evaporation into other forms of energy; the heat becomes latent. Since air in contact with water is rarely saturated with aqueous vapor, owing to the constant movement of the atmosphere, the process of evaporation, with the accompanying conversion of heat into latent heat, is a continuous process. The phenomenon is a variable one, however, for while at high temperature, both because of the greater supply of heat and because of the greater amount of water vapor that the air can hold, the process is very important and active, at low temperature it is far less considerable. This in itself is no doubt a benefit, because it tends especially to restrict the upward march of temperature when the temperature is high, but it is of minor importance when the temperature is low.

In view of the other favorable qualities of water it is perhaps not surprising to find that its latent heat of evaporation is by far the highest known. So great in truth is this quantity and so important the process that the latent heat of evaporation is one of the most important regulatory factors at present known to meteorologists.

When the sun shines upon a body of water, only a small part of the energy which the water receives contributes to the elevation of its temperature. Thus FitzGerald has concluded, from his studies of Lough Derg in Ireland during clear hot summer weather, that in the morning the surface temperature rises about 0.6 degrees per hour This, however, appears to account for but a small fraction of the solar heat which the lake had taken up; the rest must have been expended in evaporation. Another element of great importance is the transparency of water. As a result, the rays of the sun are not absorbed by the mere surface alone, but a considerable layer of water near the surface receives the heat.

At the equator the evaporation of the ocean appears to be about 2.3 meters per year, which involves more than 1 000 000 000 000 000 calories of latent heat per square kilometer. The amount of heat which is employed in evaporating water from one hundred square kilometers of the tropical ocean is accordingly vastly more than all the energy employed in the metabolism of the total population of the United States, and it amounts to more than 100 000 000 horse-power. This is equivalent to more than one

horse-power per square meter day and night throughout the year. To a greater or less extent all over the earth this same process goes on, and as a result the water vapor in the air probably averages between 15 and 20 kg. per square meter of the earth's surface, an ample supply for the formation of rain. The effect of this enormous evaporation to moderate the temperature of the tropics is very considerable; but the heat which thus disappears is not lost. Rendered latent at the place of evaporation, it is turned back into actual heat at the point of condensation, and thus serves to warm another, and cooler locality.

This process, so vast that all the water-power of the globe may be regarded as its secondary by-product, possesses in respect to its tendency to moderate and equalize the temperature of ocean, of lakes, and of the climates of all the earth, a maximal value. No other liquid could during the evaporation of a given quantity of material bind so much heat; no other vapor could yield so much heat upon condensation.

Quite as important to man as this great power of meteorological regulation is the corresponding physiological activity, evaporation of water from the skin and lungs. In an animal like man whose metabolism is very intense, heat is a most prominent excretory product, which has constantly to be eliminated in great amounts, and to this end only three important means are available,— conduction, radiation, and the evaporation of water. The relative usefulness of these three methods varies with the temperature of the environment. At a low temperature there is little evaporation of water, but at body temperature or above there can be no loss of heat at all by conduction and radiation and the whole burden is therefore thrown upon evaporation. The manner in which evaporation becomes important in temperature regulation is well illustrated by the following calculation from a chart of Rubner's. The experiments upon which the chart is based were made upon the dog, an animal which lacks man's apparatus of sweat glands. The values of the table on page 12 are only approximate.

In plants evaporation is even more important than in animals. Evidently such adaptation of the physiological processes to the conditions of the environment is enormously favored by the high latent heat of evaporation.

Temperature. Degrees.	Heat Loss by Evaporation, Per Cent.
9	16
11	19
13	22
15	25
17	27
19	30
21	32
23	32
27	36
29	42
31	58
33	64
35	79

There is still another beneficial result of this property; the great variation in the vapor tension of water which accompanies variation in temperature. Vapor tension measures the amount of vapor which is present in the atmosphere when it is in contact with a liquid and after it has become saturated with the liquid's vapor. Now, according to a well-known law the rate of increase of vapor tension, or in other words the amount of vapor which the air can hold, is greater the greater the latent heat of vaporization. Hence degree by degree there is more variation in the vapor tension of water than there could be if the latent heat were lower. Such great variability in the quantity of water which the air can hold is in meteorology the most important characteristic of aqueous vapor. The relationship between vapor tension and temperature (centigrade) is shown in the accompanying table.

Temperature. Degrees.	Vapor Tension. Millimeters.
0	4.60
10	9.16
20	17.39
30	31.55
40	54.91
50	91.98
84	417.0
92	611.0
100	760.0

These variations are what make possible both the evaporation of water and its precipitation as rain and as dew in the meteorological cycle. And therefore the high latent heat of vaporization of water is in still another manner a most favorable circumstance in its effect upon the organisms.

To sum up, this property appears to possess a threefold importance. First, it operates powerfully to equalize and to moderate the temperature of the earth; secondly, it makes possible very effective regulation of the temperature of the living organism; and, thirdly, it favors the meteorological cycle. All of these effects are true maxima, for no other substance can in this respect compare with water.

Thermal Conductivity.

The heat conduction of water is also a maximum among ordinary liquids, and though very low compared with good conductors like metals, must favor the equalization of temperature within the living cells whose structure hinders the establishment of convection currents.

Expansion before Freezing.

A final thermal property of water remains to be considered, namely, its anomalous expansion when cooled at temperatures near the freezing point.

This unique property of water is the most familiar instance of striking natural fitness of the environment, although its importance has perhaps been overestimated. If, however, water like all other common substances, steadily contracted on cooling so that its point of maximum density fell at the freezing point, it is impossible to say how great would be the disadvantage for living organisms. Certain it is that life upon the earth would be thereby very greatly restricted. For this property, together with the by no means unique phenomenon of expansion upon solidification, is very largely responsible for the permanence in liquid state of many bodies of water in cold climates. In salt water the anomalous contraction disappears, and the lack of paleocrystic

ice is due to the density of ice and to the great mass of the ocean and the movement of its waters.

There is an old experiment of Rumford's which well illustrates what conditions must have been had the contraction of water been normal and ice denser than water. He found that in a vessel filled with water, which contains ice confined at the bottom, it is possible to heat and even boil the superficial portion of the water without melting the ice. And so it would be with lakes, streams, and oceans were it not for the anomaly and the buoyancy of ice. The coldest water would continually sink to the bottom and there freeze. The ice once formed could not be melted, because the water would stay at the surface. Year after year the ice would increase in winter and persist through the summer, until eventually all or much of the body of water, according to the locality, would be turned to ice. As it is, the temperature of the bottom of a body of fresh water cannot be below the point of maximum density; on cooling further the water rises; and ice forms only on the surface. In this way the liquid water below is effectually protected from further cooling and the body of water persists. In the spring the first warm weather melts the ice, and at the earliest possible moment all ice vanishes.

Such are the important thermal properties of water, and in briefest outline their unique fitness for the living mechanism. No other known substance could be substituted for water as the material out of which oceans, lakes, and rivers are formed, and as the substance which passes through the meteorological cycle without radical sacrifice of some of the most vital features of existing conditions. Ammonia in these respects is the only substance now known which approaches the fitness of water. But not only is it almost inconceivable that ammonia should ever occur in sufficiently vast quantities upon a planet's surface, but it is evident as well that ammonia wholly lacks the qualification of anomalous expansion, and also in some of the most important of the other thermal properties falls far short of water; while in latent heat of melting and in specific heat its advantage over water is inconsiderable.

It is obvious that upon a body like the earth the state of the oceans, and the meteorological phenomena, are of the utmost

importance to all living things. Unless these be favorable, human experience and reflection alike agree that life could not widely exist. It seems therefore almost safe to say, on the basis of its thermal properties alone, that water is the one fit substance for its place in the process of universal evolution, when we regard that process biocentrically.

The Action of Water upon Other Substances.

Although the thermal properties of water make up the classical subject matter for discussions of the fitness of the natural environment, other no less important physical properties exist. Such especially are those characteristics of liquid water which in no small measure determine the nature of the resulting physicochemical systems when other substances, whether soluble or insoluble, crystalline or colloidal, are brought into contact with it; I mean the solvent power, the dielectric constant, together with the related ionizing power and the surface tension.

Water as a Solvent.

As a solvent there is literally nothing to compare with water. In truth its qualifications are on this point so uniq 1 and obvious that nobody seems to have taken the trouble to gather together the evidence, and accordingly, beyond the bare assertion, a brief statement of the facts is not easy. In the first place, the solubility in water of acids, bases, and salts, and most familiar classes of inorganic substances is almost universal.

Relatively few of these bodies are highly insoluble, very many are exceedingly soluble in water. Apart from their electrolytic dissociation and hydrolysis, which will be later discussed, the chemical changes wrought upon such dissolved substances in solution are commonly very unimportant. For chemical inertness, depending upon great stability, is a most significant characteristic of water, and undoubtedly a highly advantageous one as well. On the whole the best evidence for the efficiency of water as a solvent of inorganic substances is to be found in the data of geology. Of all geological agents water appears to have been by far the most active within the periods of which investigation is

made possible by the geological record. Rainfall, the movement of surface streams and of water beneath the ground, and wave action, all contribute to the work of disintegration, sedimentation, etc., partly by dissolution of soluble material, partly by mechanical action. But mechanical action is itself much increased by the loosening which earlier dissolution has caused. In this manner the great solvent power of water throughout its meteorological cycle largely contributes to the mobilization of many materials which could not otherwise be brought to the organisms which need them.

It has been calculated by Murray that the total yearly run-off of all the rivers of the earth is about 6 500 cubic miles, carrying nearly 5 000 000 000 tons of dissolved mineral matter and prodigious quantities of sediment. The average composition of such water has been estimated as follows:

		Parts per Million.
Potassium as	K_2O	2.40
Sodium as	Na_2O	7.10
Lithium as	Li_2O	0.20
Calcium as	CaO	43.20
Magnesium as	MgO	14.70
Manganese as	Mn_3O_4	1.20
Iron as	FeO	2.80
Aluminum as	Al_2O_3	3.10
Silicon as	SiO_2	16.40
Carbonic acid	CO_2	46.00
Phosphorus as	P_2O_5	0.30
Nitric acid as	N_2O_5	3.80
Sulphuric acid	SO_3	8.00
Chlorine	Cl	3.70
Ammonia	NH_3	0.07
Total mineral matter,		152.97

It is of course almost exclusively to these constant accessions that the ocean owes its salinity, which in the course of time has reached well-nigh inconceivable magnitude. The common salt alone in the oceans of all the earth amounts to not less than 35 000 000 000 000 000 tons. Not less significant of the solvent

power of water is the variety of elements whose presence in sea water can be demonstrated, thus proving that the total store of them is in any case enormous. They include hydrogen, oxygen, nitrogen, carbon, chlorine, sodium, magnesium, sulphur, phosphorus, which are easily demonstrated; further, arsenic, caesium, gold, lithium, rubidium, barium, lead, boron, fluorine, iron, iodine, bromine, potassium, cobalt, copper, manganese, nickel, silver, silicon, zinc, aluminum, calcium, and strontium.

Equally striking is the evidence in regard to the first stages of this geological process. Under the action of water, aided to be sure in many cases by dissolved carbonic acid, every species of rock suffers slow destruction. All substances yield *in situ* to the solvent work of water, and the dissolved parts may all be found in the great final reservoir, the ocean. It has been proved that nearly every one of the substances which are thus set in motion upon the face of the earth are placed under contribution by life, for biochemical analysis reveals them as constituents of living organisms, absorbed either on their way down from the mountain tops to the ocean, or by the marine flora and fauna.

Not less valuable to the community of living things than the dissolution of the rocks is the disintegration and transport of solid material, largely dependent thereon, which among its many results includes the preliminary steps of soil formation. By these familiar and enduring geological means chemical substances are mobilized in the greatest variety of forms and conditions and thus rendered available for the living organism. It is clearly evident from the chemist's long experience with solvents that no other fluid could permanently carry on this process with such acceptable regularity and efficiency. For no other chemically inert solvent can compare with water in the number of things which it can dissolve, nor in the amounts of them which it can hold in solution; and of course any chemically active solvent must sooner or later exhaust itself by its chemical action, when the cycle must cease. Here then is a fitness of water which is open to doubt.

Let us turn for further proof to the organism itself, taking blood serum as a source of information. The composition of this substance (in the case of the cow) is roughly as follows:

	Parts per 1 000.
Water	913.6
Protein	72.5
Sugar	1.05
Cholesterine	1.24
Lecithine	1.68
Fat	0.93
Organic phosphoric acid	0.01
Na_2O	4.31
K_2O	0.26
CaO	0.12
MgO	0.45
Cl	3.69
P_2O_5	0.08

Most of these substances are in solution, and unquestionably a host of others are present with them, in small and varying amounts. Among these may be mentioned, iodine, bromine, iron, sulphates, urea, ammonia, benzoic acid, amino-acids, etc. But indeed all substances found in urine (see below) also occur in blood. It cannot be doubted that if the vehicle of the blood were other than water the dissolved substances would be greatly restricted in variety and in quantity, nor that such restriction must needs be accompanied by a corresponding restriction of the life processes.

The composition of the urine provides another excellent illustration of the utility of the solvent power of water. In the course of its complex chemical processes a higher organism produces a host of end-products which must be removed, and also finds itself accidentally in possession of a great variety of other useless substances which require excretion. The solvent power of water is one of the great factors in facilitating this task. Human urine has been reported to contain in solution the following substances: urea, carbamic acid, creatinine, creatine, uric acid, xanthine, guanine, hypoxanthine, adenine, paraxanthine, heteroxanthine, episarkine, epiguanine, oxalic acid, allantoine, hippuric acid, phenaceturic acid, benzoic acid, phenolsulphuric acid, skatoxylsulphuric acid, paraoxyphenylacetic acid, homogentisic acid, urobiline, urochrome, uroerythine, glucose, levulose, lactose, numerous compounds of glycuronic acid, glycine, alanine, leucine, tyrosine, and other amino-acids, various enzymes, putrescine,

cadaverine, and countless other organic substances, chlorides, bromides and iodides, phosphates and sulphates, potassium, sodium, ammonia, calcium, magnesium, iron, carbonic acid, nitrogen, argon, etc.

Here again it is sure that such variety could not be attained with another solvent. It is no exaggeration to say that except atmospheric oxygen and carbonic acid, nearly all the food of living organisms is water borne, and all material in its passage into the body, through the body, and out of the body nearly always employs the same vehicle. Certainly no other form of transport would be so efficient and so economical.

Ionization.

If therefore aqueous solutions are, apparently of necessity, the very basis of the life processes, the state of substances when in this condition, and also when in contact with water, is of vital importance. Here two properties of water, the dielectric constant and the surface tension, exert a cardinal influence.

Among the phenomena of solution those which are related to electrolytic dissociation, as suggested by the hypothesis of Arrhenius, have deservedly received a great deal of attention since the secure establishment of the new science of physical chemistry, in the eighties of the last century. In the course of time the belief that in aqueous solution the molecules of all acids, bases, and salts are more or less split into particles which bear electrical charges has been universally accepted. These so-called ions are the source of nearly all the electrical phenomena of solution, whether in batteries, in the manifestations of animal electricity, or in simple conduction through an aqueous solution. But the more familiar electro-chemical processes are by no means the only results of ionization. An infinite number of chemical interactions between dissociated bodies follow inevitably. These changes are not, to be sure, decisive and irreversible, but balanced actions which vastly increase the variety of substances that exist in water.

It is certain that the extent and variety of ionization in water far surpass what is possible in any other solvent. One reason for this is most simple. The ionizing substances are so very much more

often soluble in water than in any other solvent, and when soluble are in general so much more highly soluble, that the opportunity for ionization in water is quite unparalleled. Further, ionization in solution unquestionably depends upon the dielectric constant of the solvent, in accordance with the principle first stated by Nernst that the greater the dielectric capacity of the solvent, the greater is the degree of electrolytic dissociation of substances dissolved in it, when the conditions are otherwise the same. This is the case because the tendency of the electrically charged ions to reunite and form electrically neutral molecules must be less the greater the dielectric constant of the solvent. Now the dielectric constant of water is nearly the highest at present known, and therefore ionization in water is on that account also more extensive than in almost any other solvent.

Finally for reasons that are not yet understood, the process of ionization in other solvents than water is a much more complex affair, and there can be no doubt that such complexity limits the phenomena which are dependent upon ionization.

Physiologicaliy, as researches of the last twenty years clearly prove, the action of ions is of fundamental significance. The brilliant investigations of J. Loeb, and the long series of studies by various other physiologists of the influence of electrolytes upon colloids, form perhaps the most telling evidence for this belief. At all events, there is no question that the simple equilibria between acids and bases and salts are of extreme importance in the physiological processes. They lie at the very basis of the structure of all protoplasm, and the sure and definite relations between such bodies provide, as it were, a secure foundation for the more complex organic structures.

More obvious is the value of ions as sources of electricity. If the older electro-physiology of the third quarter of the nineteenth century has proved in some respects a sterile field, there can yet be no doubt that more subtly and quite apart from the nervous impulse and electrical fishes, electrical phenomena are everywhere involved in the most intimate of the physiological processes.

Even without further discussion of a subject that must soon lead into difficult and highly technical considerations, I feel sure that the existence of another important fitness of water is patent.

For ions are evidently a real contribution to the richness of the environment. They enhance the variety of chemical substances and of chemical reactions; they constitute a group of singularly mobile chemical agents; they provide electricity; and finally, aqueous solutions are by far the best source of ions.

Surface Tension.

Of all common liquids except mercury, water has the greatest surface tension. This fact is of enormous moment in biology, most obviously perhaps in its influence upon the soil. For surface tension and density determine the height to which a liquid will rise in a capillary system, and thus it comes about that the principal factor in bringing water within the reach of plants is the exceptional surface tension of water. The nature of the case is well explained by Hilgard:

"The liquid water held in the pores of the soil, in the form of surface films representing the curved surface seen in capillary tubes, and therefore tending to cause the water to move upwards, as well as in all other directions, until uniformity of tension is established, is of vastly higher importance to plant growth than hygroscopic moisture. It not only serves normally as the vehicle of all plant food absorbed during the growth of the usual crops, but also, as a rule, to sustain the enormous evaporation by which the plant maintains during the heat of the day a temperature sufficiently low to permit of the proper operation of the processes of assimilation and building of cell tissue."

The rise of water in capillary systems resembling soil, under the action of surface tension may be as much as ten feet. In soil itself the highest rise under the usual circumstances is unquestionably as much as four or five feet; but if the surface tension of water were like that of most liquids it could be, under similar conditions, but two or three feet. There seems to be little doubt that the rise of fluids in tall plants is also in large part due to the action of surface tension, and accordingly it must be much favored by the magnitude of that quantity in the case of water.

Finally, surface tension is of great importance; indeed, in simple

cases the one effective agent, in the phenomenon called adsorption.* On the basis of thermodynamical considerations first developed by Willard Gibbs, it is easy to show that whenever the dissolution of a substance changes the surface tension of a solvent, the distribution of the dissolved substance will not be strictly homogeneous. If the solution has a lower surface than the solvent, the surface of the solution will become more concentrated than the interior; or if the surface tension of the solution be greater than that of the solvent, the surface of the solution will become less concentrated than the interior. This result, quite insignificant in simple solutions, becomes a matter of much moment when, as in the case of suspensions of fine particles like animal charcoal, in emulsions, jellies, or any other system of like disperse heterogeneity of physical constitution, there occurs very great increase of surface area. Then it is that adsorption becomes a factor of the greatest weight; for, other things being equal, the total force of surface tension in a system is proportional to the area of surface. Under these circumstances dissolved substances are no longer distributed with any approach to equality or regularity in the system, but they collect at the surface in very great quantities, and in the most irregular manner.

Now, of all known physical structures there is none which rivals protoplasm in its fine complexity, and adsorption is therefore unquestionably a prominent agent in deciding its physico-chemical constitution. Moreover, adsorption influences and complicates almost every process of chemical physiology, for no product of life is without its colloids, i. e., substances which are finely divided and therefore endowed with great surface areas. The evidence of this universal importance of adsorption in biology is not to be briefly presented, but it may be found in almost endless profusion in such works as those of Freundlich and Bechhold.

It must not be supposed that the phenomena of adsorption in biology are simple and exactly understood. What is certain is that they are universal, and that surface tension lies at the root of the matter. This is because all living things are colloidal, and

* A familiar example of adsorption is the use of boneblack to decolorize syrup in the process of sugar refining. The colored matters are almost completely removed from solution, and cling to the surface of the charcoal.

I am inclined to think that most physiologists will admit that life without colloids is probably unthinkable, even in a world very differently constituted from our own. Colloidal structures are in fact the first and greatest factors in physical complexity of organization, and the principal force, unless it be in exceptional cases an electrical charge due to ions, which operates upon the colloidal structures, is surface tension. This then is another striking fitness of water above all other things.

Such are the facts which I have been able to discover regarding the fitness of water for the organism. The following properties appear to be extraordinarily, often uniquely, suited to a mechanism which must be complex, durable, and dependent upon a constant metabolism; heat capacity, heat conductivity, expansion on cooling near the freezing point, density of ice, heat of fusion, heat of vaporization, vapor tension, freezing point, solvent power, dielectric constant and ionizing power, and surface tension.

In no case do the advantages which these properties confer seem to be trivial; commonly they are of the greatest moment; and I cannot doubt, even after allowances have been made for the probability of occasional fallacies in the development of an argument which though simple is beset with many pitfalls, that they are decisive. Water of its very nature, as it occurs automatically in the process of cosmical evolution, is fit, with a fitness no less marvelous and varied than that fitness of the organism which has been won by the process of adaptation in the course of organic evolution.

If doubts remain, let a search be made for any other substance which, however slightly, can claim to rival water as the *milieu* of simple organisms, as the *milieu intérieur* of all living things, or in any other of the countless physiological functions which it performs either automatically or as a result of adaptation.

In truth, Darwinian fitness is a perfectly reciprocal relationship. In the world of modern science a fit organism inhabits a fit environment, whose primary constituent is water.

DISCUSSION.

PROF. W. T. SEDGWICK.* *Mr. President and Fellow-Members:* It is, I think, now universally recognized that in order to have great poetry you must have a great subject. Comedy will always rank below tragedy, for this reason: Comedy deals with humor and with the lighter aspects of human life; tragedy deals with those darker, graver, and more solemn aspects with which humor has nothing to do. I think we are fortunate — those of us who are interested in water and water supplies — in being able, after hearing Professor Henderson's remarkable paper, to conclude that we have a great and worthy subject upon which to spend our lives. Water is an immense subject. It is more, — it is unique; and, as Professor Henderson has shown us, it would be impossible for us as living things to have the wonderful properties of life and yet to get along with water.

Professor Henderson began by speaking of Thales, who, as you remember, thought that all the stuff of the universe was fundamentally water. Now, Thales had traveled in Egypt and Babylonia, the two great centers of ancient civilization, and he had seen there in the Tigris and the Euphrates and in the Nile wonderful examples of rivers on the shores of which stood the most advanced civilizations of the time. The irrigation works in Babylonia, and also in Egypt, excited his astonishment. But what Thales didn't know was that in addition to the civilizations of the Nile and of the Euphrates were to come grander civilizations on the shores of the Mediterranean far surpassing those in importance, and leading on to the Europe and the America of to-day. Mankind has been associated with water and with great water courses and with great seas from the earliest times until now. Man has shunned, comparatively speaking, the high lands and the deserts, and has built his home beside the waters, beside great waters. We say that public opinion is the resultant of individual opinions blended together. We may say equally well that all these civilizations of ours are the resultant of life by great waters and life upon the products of great waters; and, as Professor Henderson has well said, we are ourselves largely made of water.

* Professor of Biology and Public Health, Massachusetts Institute of Technology.

This subject, it seems to me, is one that strangely opens the mind. I could not help thinking, as he was talking, of how Keats, the poet, chose for his epitaph: "Here lieth one whose name was writ in water." Poor Keats was defeated, — at the time at least he seemed defeated; he seemed a failure, he died early, probably of tuberculosis, and in despair chose as his epitaph, "Here lieth one whose name was writ in water." And yet, after hearing Professor Henderson, we cannot help feeling that no other monument could possibly be so good to write one's name upon for all eternity as a monument of water.

But, gentlemen, the important point, it seems to me, for us this afternoon is to felicitate ourselves upon the fact that once more — and this has happened many times — we have had at one of our meetings a man of high distinction, a man of science, who has brought us the latest results of his work, and enabled us to stand aside for a moment from the routine of professional life and look out upon our life work as something great and worthy. We have had in the past important papers from men like Professor Drown, who, alas, has gone; and from other great leaders in hydraulics and in chemistry and in biology. But I venture to say that we have never had a more fundamental and more far-reaching or a more important paper than that to which we have just listened; and I am very sure I express your gratitude, as I do my own, when I say this, and that Professor Henderson may take with him the assurance that every man of us has listened eagerly to what he has said. I have watched the faces of the audience as he was reading, and I feel sure that every one of us has got much from his paper. I hope that from time to time the Association may have papers of this kind, if it can get them, for certainly it is a fine thing thus to bring together men of the laboratory and men of the field. You could doubtless teach Professor Henderson a great deal about some aspects of water, and he has shown that he can teach us likewise.

PROF. DWIGHT PORTER.* One statement of Dr. Henderson's that was new to me was with reference to the constant increase in density of salt water in freezing. If I remember rightly, fresh water in the act of cooling from 39 to 32 and freezing becomes

*Professor of Hydraulic Engineering, Massachusetts Institute of Technology.

lighter and remains on the surface, and thereby protects the water underneath from freezing solid. I have been wondering what results from this principle as to the constant increase in density of salt water. Do bodies of salt water tend to freeze solid from top to bottom? If not, what prevents?

PROFESSOR HENDERSON. I am afraid I can scarcely answer that question adequately. Of couse it lies very far from my own field. I was quite as much surprised as anybody could be when I found out, in making a systematic survey of the properties of water, a couple of years ago, that the anomalous expansion did not apply to all waters. There is, of course, the phenomenon of anchor ice, so-called, and it is a fact that more often ice is found at the bottom of bodies of salt water than at the bottom of bodies of fresh water. But I think the only reason that salt water does not, now and then, freeze at the bottom and continuously up is that ice itself is so much lighter than water. That is a characteristic of ice that cannot be destroyed by the fact that it happens to be formed in salt water. And that is in itself a sufficient and curious comment upon the old teleological and natural theological speculations in connection with water. The old theologians, in picking out the anomalous expansion of water, picked out the one peculiarity of water that is of no particular importance to their cause, and threw away all the good ones, without exception.

SOME RECENT EXPERIENCES IN THE DEFERRIZATION AND DEMANGANIZATION OF WATER.

BY ROBERT SPURR WESTON, CONSULTING SANITARY ENGINEER.

[*Read February 11, 1914.*]

Since Salbach's discovery* in 1868, it has been known that certain ground waters could be freed from iron by aëration followed by filtration through gravel or sand; and since 1874, when the Charlottenburg works were completed, the introduction of this method has been rapid, especially in Germany, where such large cities as Berlin, Hamburg, Breslau, Dresden, Leipsic, Charlottenburg, Kiel, Brunswick, Hannover, and others are supplied in this way, some of them supplanting their filtered surface-water supplies because of the greater attractiveness and safety of the purified ground water.

In America the development has been slower. There are plants in successful operation at Far Rockaway, N. Y., and along the New Jersey coast; at West Superior, Wis.; Richmond, Mo.; Garretsville, Ohio; and in New England at Marblehead, Reading, Middleboro, and a few other places.

Because the original problem has been complicated in recent years, it will be well to review briefly the principles underlying the deferrization process.

PRINCIPLES OF DEFERRIZATION.

Iron exists in water as iron hydrate. This is soluble and unoxidized, and usually accompanied by mineral salts, carbon dioxide, or other gases, and perhaps by organic matter or manganese.

Iron can be precipitated from most ground waters — those low in manganese and vegetable-organic matter — by simple aëration by spraying, followed by filtration through sand or even fine gravel. Provided the water be properly treated beforehand,

* "Berichte über die Erfahrungen bei Wasserwerken und Wasserversorgungen," Dresden, 1893.

the kind of filter, whether slow or rapid, whether filled with fine sand or coarse, has little to do with taking out the iron.

Simple aëration oxidizes the iron from the soluble unoxidized form to the insoluble oxidized form, from ferrous to ferric hydrate. It also effects the removal of some of the carbon dioxide. When one realizes that 1 part of oxygen per million will oxidize 7 parts of iron, it is easy to understand how an excess of oxygen may be obtained by a slight exposure to the air. The following table by Oesten* shows the degree of absorption of oxygen by water after being sprayed from various heights, at ordinary temperature and pressure.

TABLE I.

Height of Fall. Inches.	Oxygen Absorbed. Parts per Million.
4	4.42
10	5.00
20	5.75
40	9.73
80	10.57

If the absorption of oxygen and the oxidation of the iron were all, the problem would be easy. In many cases it is easy, and because of this fact many have been lead astray by the apparent simplicity of the process and have designed plants which have failed or have operated uneconomically.

Ferrous (iron) hydrate oxidizes quite readily to ferric hydrate; this latter is insoluble and in most cases coagulates and precipitates rapidly. Some waters, however, contain interfering substances which prevent the precipitation of the iron, holding it in the semi-soluble or colloidal form, and making its removal by filtration difficult. It is not the oxidation but the precipitation of the iron which is difficult to accomplish.

CAUSES OF INTERFERENCE.

It is to explain some of these causes of interference that this paper is written. Three of them are as follows: Carbon dioxide, organic matter, manganese.

* Schillings Jour. für Gas. und Wasserversorgung, *34*, 283.

Carbon Dioxide. All acids interfere with the precipitation of ferric hydrate, including the carbonic acid which has dissolved the iron from the soil; consequently it is necessary to so treat the water prior to filtration that not only will the iron be oxidized, but the carbon dioxide be eliminated as much as practicable. With waters of peculiar organic composition, especially those from beneath alluvial deposits or marshy areas, aëration can be carried so far as to make it impossible to coagulate the oxidized iron before filtration. These phenomena have been noticed at Reading, Mass.; Superior, Wis., and at other places.

Organic Matter. Not all organic matter interferes with the precipitation of iron. For example, the organic matter from deep wells in geologically old deposits not only does not interfere with the precipitation of iron, but assists in its removal; and in turn the iron causes the precipitation of the organic matter. They mutually precipitate one another.

However, other kinds of organic matter interfere seriously with the deferrization process, and the writer is of the opinion that the fresher and newer the organic matter, the more troublesome it is. Experiments have shown that extracts of freshly fallen leaves and grasses delay, while extracts of lignite and some peats assist, the deferrization process. They have also shown that all gelatinous bodies, like glue, gluten, and gums, interfere. These are much more apt to be present in actively decaying organic matter than in old deposits.

Certain kinds of organic matter, or, as the writer imagines, the new matter or that rich in humic acid, interfere with the coagulation of the iron when the water is excessively aërated. Lounsbury* found that at Superior, Wis., better results were obtained without the aërator than with it, because an excess of oxygen was already present in the water because of a leaky suction, and because the presence of carbon dioxide, which would be reduced from 12 to 4 parts per million by passing the water through the aërator, was necessary to prevent the soluble organic matter from interfering with the deferrization process; i. e., prevent the humic acid from combining with the iron.

Similar results were obtained at Reading, Mass., and the con-

* Trans. Am. Soc. C. E., *64*, 182.

clusion that aëration can be too thorough was forced on the writer's unwilling mind. There the peculiar organic matter appeared in and disappeared from the water suddenly, and its effect was unmistakable. It was also learned at Reading that the iron could be induced to coagulate and the interference of organic matter avoided, by contact with broken stone, not by trickling the water over it, as in the rieseler of Piefke or in one of the many types of aërator, but by passing the water through submerged stones or coarse coke in a roughing filter.

Of course the same effect could be secured, but at a prohibitive cost, by storing the water for a very long period, but contact between the water and a rough surface like that provided by coke or broken stone, on which iron hydrate has accumulated, greatly accelerates the process, as shown by Clark.* The submergence of the filtering material prevents the loss of the CO_2 and the contact brings about the coagulation of the iron, notwithstanding the presence of a small amount of this interfering gas. In these cases, plants can be designed to remove part of the CO_2 by aëration and then bring about a precipitation of the iron by contact with submerged material.

Manganese. Until the Breslau calamity in 1906, when the manganese in the well supply rose suddenly to 220 parts per million, little attention was paid to manganese. Even water analysts paid little attention to it, and in this country its presence was ignored. It is true that a well water was condemned by Mr. Allen Hazen† in 1898 because of its high manganese, and Mrs. Ellen H. Richards reported that the deposits in the Brookline mains contained a high percentage of manganese. It has rarely, if ever, been reported in the published results of analyses by boards of health and water commissioners. Recently its presence at Reading and elsewhere, and the simplification of the methods for its determination, have caused it to be given proper attention.

Chemically, manganese is closely related to iron. It, however, reacts and precipitates more slowly, and it possesses the power of preventing the removal of the last traces of iron unless it itself be removed at the same time.

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* Journal N. E. W. W. A., *11*, 277.
† Trans. Am. Soc. C. E., *64*. 174.

In a distribution system supplied with well water containing iron and manganese, deposits will be found nearest the wells which contain iron but little or no manganese, while those points farthest distant will be colored black with manganese.

At Hannover the writer was presented with three samples of precipitate as follows:

No. 298, from the distribution system before filters were introduced.

No. 299, from the filter material.

No. 300, from the water tower.

These samples were analyzed, the results being shown in the following table:

	Number.		
	298.	299.	300.
Iron (Fe)	57.89 per cent.	34.72 per cent.	14.27 per cent.
Manganese (Mn)	0.30 per cent.	1.24 per cent.	7.15 per cent.
Ratio (Mn : Fe)	1:193	1:28	1:3

For complete demanganization, it is necessary to increase the contact treatment beyond that necessary for deferrization alone.

EXPERIMENTS.

During 1913 the writer conducted three experiments for the Cohasset Water Company and the towns of Middleboro and Brookline, respectively.

The average analyses of the three waters are as shown by the table on page 32.

The remarkable fact about the above waters is the similarity of many of their characteristics; they have about the same turbidity, color, and free ammonia; they are all soft, contain little mineral matter, and their chlorine content is what one would expect from their location. They differ in the amounts of oxygen consumed, albuminoid ammonia, nitrates, iron, manganese, and carbon dioxide; it is these differences which are significant.

TABLE II.

(Parts per Million.)

Source of Sample.	Cohasset Well.	Brookline Wells.	Middleboro Well.
	Averages.		
Turbidity, silica standard	3	4	11
Color, platinum standard	44	29	41
Oxygen consumed	5.6	1.88	.65
Nitrogen as Free Ammonia	.052	.061	.049
Nitrogen as Albuminoid ammonia, total	.097	.088	.046
Nitrogen as Nitrites	.000	.001	.001
Nitrogen as Nitrates	.04	.19	.42
Chlorine	14.3	8.5	6.6
Alkalinity	30	40.1	
Hardness by soap method	16	47.1	26.6
Iron (Fe)	.73	.60	1.49
Residue on evaporation, total	80	105	68
Manganese (Mn)	.23	.26	.75
Carbon dioxide (free and half bound)	49.82	31.8	45
Dissolved oxygen	1.58	1.32	3.02

COHASSET SUPPLY.

The most difficult water to treat is that from Cohasset. This water is from a well which is fed both in the natural way and by irrigating the ground in the vicinity with the highly colored Lily Pond water. The objectionable features are the high amounts of organic matter and carbon dioxide. The incomplete oxidation of the organic matter originally in the Lily Pond water is shown by the analytical results. Manganese is also present and of course interferes with the deferrization process.

Experiments.

The first set of experiments was conducted by the Norwood Engineering Company, with the assistance of Mr. A. L. Gammage, of the writer's office. The devices used consisted of an aërator of the spray type discharging over slats into a series of subsiding basins having a capacity equivalent to 3.5 hours' flow. The water from the last of these basins discharged into a small Wilson filter containing a depth of 2 ft. of sand, having an effective size of from .35 to .40 mm. and operating at a rate of 103 million gallons

per acre per diem. The aërator reduced the CO_2 from 30 to 16 parts per million.

Two experiments were first made, as follows:

Experiment I. Treatment by aëration and filtration without the addition of chemicals.

Determination.	Parts per Million.		
	Raw.	Filtered.	Percentage Removed.
Average color	40	26	35
Average iron	0.65	0.40	38

Experiment II. Like I, with the addition of 1 gr. of sulphate of alumina and 1 gr. of soda per million.

Determination.	Parts per Million.		
	Raw.	Filtered.	Percentage Removed.
Color	40	20	50
Iron	0.70	0.40	43
Alkalinity	—	22	—
Carbon dioxide	—	16	—

These tests were unsatisfactory, insufficient iron and color being removed. The doses of chemicals were changed with the following results.

Experiment III. Without aëration and with the addition of 2 gr. of sulphate of alumina and 0.5 gr. of soda per gallon.

Theoretical period of coagulation, fifty-eight minutes.

Determination.	Parts per Million.		
	Raw.	Filtered.	Percentage Removed.
Color	30	10	67
Iron	0.60	0.25	58
Alkalinity	10	3	70
Carbon dioxide	30	23	23

As will be noted, these results are greatly superior to those obtained in Experiment II. Samples of raw water when allowed to stand over night deposited iron, but samples of filtered water did not, showing that the removal of color helps to prevent the iron from precipitating.

Experiment IV. Two additional layers of slats were added to the aërator, making three in all. The experiment was conducted with aëration and filtration alone, without the addition of chemicals.

Determination.	Parts per Million.		
	Raw.	Filtered.	Percentage Removed.
Color	30	24	20
Iron	0.5	0.45	10
Alkalinity	8	8	0
Carbon dioxide	38	10	74

The better removal of carbon dioxide indicates the better aëration obtained with the new aërator; the degree of deferrization, however, is less.

Experiment V. Like IV, but with the addition of 0.5 part of bleaching powder per million and 1 gr. of sulphate of alumina per gallon.

Determination.	Parts per Million.		
	Raw.	Filtered.	Percentage Removed.
Color	27	15	44
Iron	0.55	0.30	45
Alkalinity	10	4	60
Carbon dioxide	28	11	61

This experiment shows a great improvement over the previous one, and, furthermore, no iron deposited from the water when standing over night. The raw water precipitated readily after standing.

Experiment VI. Like IV, with the addition of 1.5 gr. of sulphate of alumina and 0.5 gr. of soda per gallon.

Determination.	Parts per Million.		
	Raw.	Filtered.	Percentage Removed.
Color	30	3	90
Iron	0.55	0.40	27
Alkalinity	9	4	55
Carbon dioxide	30	11	66

It will be noted that the color was removed almost completely, but that the treatment was insufficient for the precipitation of the iron. The sample of filtered water, however, stood two days without precipitating iron or increasing in turbidity.

Experiment VII. The coagulating basin was increased by two thirds, or to about 1.5 hours' flow. No chemicals were added, but a 5-ft. layer of crushed stone was placed in the tank beneath the aërator. Part of this stone was submerged.

Determination.	Parts per Million.		
	Raw.	Filtered.	Percentage Removed.
Color	30	25	17
Iron	0.6	0.55	8
Alkalinity	11	11	0
Carbon dioxide	39	8	79

Experiment VIII. Like VII, but with the addition of 1.5 gr. of sulphate of alumina and 0.5 gr. soda per gallon.

Determination.	Parts per Million.		
	Raw.	Filtered.	Percentage Removed.
Color	30	4	87
Iron	1.05	0.50	52
Alkalinity	11	7	36
Carbon dioxide	39	13	67

There were eight parts of carbon dioxide per million in the water passing through the crushed stone in the aërator. In the water leaving the bottom slats there were twelve parts per million; in that leaving the crushed stone, five parts per million, and in that in the first barrel, only three parts per million, the addition of the sulphate of alumina again increasing the carbon dioxide to 23 parts per million.

Experiment IX. Like VIII, with the addition of three parts of bleaching powder per million.

Determination.	Parts per Million.		
	Raw.	Filtered.	Percentage Removed.
Color	30	0	100
Iron	1.10	0.23	79
Alkalinity	12	8	33
Carbon dioxide	38	11	71

These results are satisfactory, although they might be obtained with less addition of chemicals, provided the apparatus was arranged differently.

Experiment X. Like VII, but with the addition of 0.5 part of bleaching powder per million, 1.5 gr. of sulphate of alumina and 1.0 gr. of soda per gallon.

Determination.	Parts per Million.		
	Raw.	Filtered.	Percentage Removed.
Color	30	6	80
Iron	1.15	0.40	70
Alkalinity	12	15	25
Carbon dioxide	37	7	81

Experiment XI. Like VII, but with the addition of 1.5 parts of bleaching powder per million.

Determination.	Parts per Million.		
	Raw.	Filtered.	Percentage Removed.
Color	30	24	20
Iron	1.15	0.70	39
Alkalinity	12	12	12
Carbon dioxide	38	3	92

These results, which were obtained in December, 1912, showed that satisfactory results could be obtained by the addition of bleaching powder to care for the organic matter, and sulphate of alumina and soda; but with an expenditure for chemicals of about $3.50 per million gallons.

To determine the feasibility of deferrization without chemicals when using mechanical filters, further experiments were conducted between January 17 and March 24.

The apparatus was the same as used during the previous experiments, and arranged as follows:

1. A wooden tank 3 ft. square, filled to the depth of 5 ft. with coarse broken stone.

2. A sprinkler, made by punching one hundred holes, each $\frac{1}{16}$ of an inch in diameter, in the bottom of an ordinary metal pail. The bottom of the sprinkler was 15 in. above the surface of the stone in the tank (the so-called trickler or rieseler).

3. Five barrels arranged in series; these served as a subsiding basin.

4. A small mechanical filter.

The apparatus was so arranged that the water fell 15 in. from the bottom of the sprinkler to the surface of the stones, and then trickled over the latter until the water level in the tank was reached. This level was about 6 in. above the bottom of the tank, and therefore the stones were not submerged for a depth of 4.5 ft.

Quality of the Water. During the experiments, the amount of iron in the raw water has varied between 0.40 and 1.15 parts; the amount of carbon dioxide from 40 to 56 parts; the amount of dissolved oxygen from 1.03 to 7.1 parts; the amount of color

from 35 to 50 parts; and the amount of manganese from 0.15 to 0.40 parts per million.

Rate of Filtration. Water was supplied to the aërator at the rate of 7.8 gal. per minute. This was equivalent to a rate of 50 000 000 gal. per acre per diem through the rieseler. The mechanical filter operated at the rate of 100 000 000 gal. per acre per diem.

Conduct of the Experiments. The apparatus ran from January 17 to January 22, as described. After January 22 an aërator consisting of a tray containing a 6-in. layer of stones, 1 in. to 2.5 in. in diameter, the surface of which was 5 in. below the aërator, was added. The aërator was supported by three layers of slats, spaced half an inch apart.

After February 11, the rieseler was raised so as to operate without submergence of its lower portion, and the aërator was raised so as to discharge at a point of 2 ft. above the stones.

On March 7 the pipes connecting the barrels serving as a subsiding basin were cleaned out, in order that sufficient water might be supplied to the mechanical filter.

On March 13 the first two barrels of the subsiding basin were filled with coke. This was completely submerged in the water.

Results of Experiments. Table III gives a summary of the results of these experiments.

The results of analysis of samples collected on March 24 show that the devices then in use produced the following results:

Determination.	Well Water.	Rieseler Effluent.	Filter Effluent.
Color	50	40	35
Iron	0.90	0.35	0.28
Carbon dioxide	54	8.6	8.0
Dissolved oxygen	2.17	10.39	10.25

On the above date the rieseler was operated at the rate of 50 000 000, and the filter at 100 000 000 gal. per acre per diem.

Notes on the Experiments. It will be readily observed that the bulk of the work was done before filtration. The reason for this is that contact between the water and the rough surfaces of the

stones or coke effects the displacement of the carbon dioxide by oxygen; the oxidation of the iron and the manganese, and the removal of color. The filter acts simply as a strainer. At the beginning of the experiments, the stones were clean, but in less than a month they showed a red coating. This, on analysis, was found to be iron rust mixed with some organic matter. In other words, notwithstanding the fact that the season was most unfavorable, on account of low temperature, for the establishment of contact action, the stones had begun to remove both iron and organic matter to a satisfactory degree. Having demonstrated that the iron and color could be brought below a safe limit under the most unfavorable conditions, the experiments were stopped.

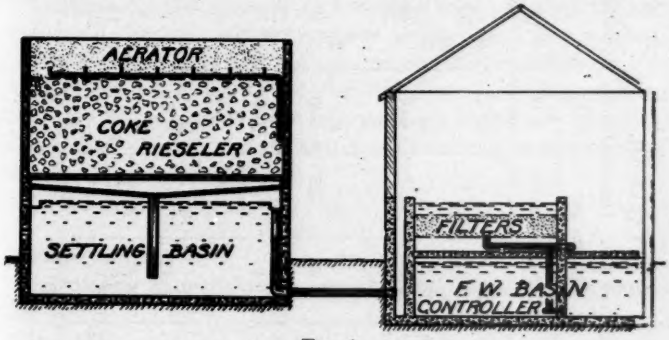


FIG. 1.

SKETCH SHOWING ARRANGEMENT OF COHASSET DEFERRIZATION PLANT.

Cohasset Deferrization Plant. Plans for a deferrization plant have been prepared by the Norwood Engineering Company and a contract has been let for their construction. The general arrangement of this plant is shown in Fig. 1. The plant consists of aërator and trickler supported above a small subsiding basin, the latter discharging into three mechanical filters of standard pattern, with filtered water basin beneath. The trickler is designed to operate at a rate of 75 million gallons per acre per diem, and is to be filled with coarse coke, 10 ft. deep. The piping is arranged so that the trickler may be operated submerged, partly submerged, or non-submerged. At certain times of year it will be impossible

TABLE III.

COHASSET WATER CO. DEFERRIZATION EXPERIMENTS.

(Parts per Million.)

	Date, 1913.	1/22	1/28	2/5	2/14	2/18	2/28	3/7	3/13	3/18	3/24
Raw Water.	Color	40	42	45	35	45	50	50	50	50	50
	Iron	.55	.40	.40	.45	1.05	.80	.80	1.15	.95	.90
	Alkalinity	17	16	17	16		16				
	CO_2	40	38	53.7	56	53	45.5	52	53	53	54
	Dissolved oxygen			2.35	1.18	7.1	1.03	1.57	1.60	2.03	2.17
	Manganese				.40	.30	.25	.20	.15	.16	.16
Rieseler Effluent.	Color	38	35	40	45	40	35	45	45	40	40
	Iron	.38	.20	.25	.25	.40	.40	.54	.45	.60	.35
	Alkalinity	17	16								
	CO_2	22	18	30.3	29	11	3.25	9	8	9	8.6
	Dissolved oxygen			9.1	5.75	10.6	10.21	10.64	*a*10.68	10.92	10.39
									*b*10.64	10.66	10.12
	Manganese				1.20	.30	.25	.20	.17	.16	.14
Filter Effluent.	Color	35	35	38	30	35	30	35	30	35	35
	Iron	.28	.10	.12	.11	.20	.30	.32	.30	.32	.28
	Alkalinity	16	16				16				
	CO_2	18	17	26.5	26	14	12	7.6	7.2	8.5	8.0
	Dissolved oxygen			12.83	7.37	10.1	10.17	10.57	10.67	10.74	10.25
	Manganese				.10	.25	.25	.20	.16	.14	.14

a = Rieseler in air. *b* = Rieseler submerged.

to aërate the water very much, and still remove the color and iron; nevertheless the period of contact may not be reduced. It is probable that the coke will have to be operated partly submerged.

BROOKLINE EXPERIMENTS.

The Cohasset water is difficult to purify because of humus matter and carbonic acid. The difficulty at Brookline is not so much the presence of specific interfering bodies, as at Cohasset, but the relatively small mass of iron to be precipitated. It is much easier, other things being equal, to precipitate five parts of iron per million than one, as may be shown by experiment.

Consequently the problem at Brookline is one of securing the economical degree of contact and the accumulation of a mass of iron hydrate on the surfaces of the material in the trickler.

Description of Experimental Devices. Four deferrization systems were tested at the Cow Bay pumping station by Superintendent F. F. Forbes and the writer. These may be described as follows:

System No. 1.

Aërator.

Coagulating basin having a capacity equivalent to 9.35 hours' flow.

Sand filter operating at a rate of 5 000 000 gal. per acre per diem, and containing a depth of 3 ft. of sand, the sand having an effective size of .41 mm.

System No. 2.

Aërator.

Coke trickler containing a depth of 2 ft. of coarse coke and operating at a rate of 75 000 000 gal. per acre per diem.

Coagulating basin having a capacity equivalent to one hour's flow.

Sand filter operating at a rate of 10 000 000 gal. per acre per diem and containing a depth of 30 in. of sand like that in Filter No. 1. The sand is supported on a layer of graded gravel one foot in depth.

System No. 3.

Like No. 2, but with a trickler having a depth of 5 ft. of coarse coke.

System No. 4.

Like No. 2, but with a trickler having a depth of 10 ft. of coarse coke.

All of the above systems were provided with suitable regulating devices or meters, and the various parts were large enough to permit safe conclusions to be drawn from the results of the experiments. For example, the tricklers were 3.0 and the filters 2.5 ft. in diameter.

It will be noted that the systems differ from each other chiefly in the character and degree of preliminary treatment before filtration; Filter No. 1, however, operated only one half as fast as Filters Nos. 2, 3, and 4.

The tricklers were put in service on August 1; the filters on August 6, and were operated as long as weather permitted.

Qualitative Results. The four systems were fairly efficient at the start, then the efficiency deteriorated slightly, and finally improved steadily until the end of the experiments. Over two hundred samples of water have been analyzed to determine the efficiencies of the four systems, but for the purpose of this paper the increase in the amount of dissolved oxygen, the decrease in the amount of carbon dioxide gas due to aëration, and the removal of iron will sufficiently illustrate the comparative qualitative efficiencies of the four systems.

The efficiency of the preliminary treatment is dependent largely upon the amount of dissolved oxygen added to the water and the amount of carbon dioxide removed, for the reason that the former assists and the latter retards the change of the iron from the soluble hydrate into the insoluble oxide of iron or rust. The removal of iron is the best index of the efficiency of the plant, and all of the many analyses which have been made show that the removal of manganese and turbidity is roughly proportional to the removal of iron. Filter No. 1, however, which operates at half the rate, removes color equally well with Filter No. 4.

TABLE IV.

Dissolved Oxygen and Carbon Dioxide.

(Parts per Million.)

Date.	Wells.		System No. 1.		System No. 2.		System No. 3.		System No. 4.	
	Dissolved.		Dissolved.		Dissolved.		Dissolved.		Dissolved.	
	O.	CO_2.	O.	CO_2.	O.	CO_2.	O.	CO_2.	O.	CO_2.
Aug. 7	1.52	48.0	7.52	21.0	7.62	15.0	9.83	12.0	10.00	8.2
Aug. 21	1.22	41.4	7.87	14.2	9.21	13.4	9.98	10.2	9.36	9.6
Sept. 4	1.25	22.6	6.87	8.3	8.19	6.5	10.57	7.6	9.20	5.8
Sept. 18	1.61	23.4	7.83	11.7	8.67	7.8	9.06	7.5	9.22	5.6
Oct. 2	2.02	24.8	8.04	9.0	8.55	5.9	9.15	5.5	9.30	4.2

The following tables show the results of preliminary treatment in the four systems with regard to the amount of dissolved oxygen, carbon dioxide, and iron.

TABLE V.

IRON.

(Parts per Million.)

Date.	Wells.	System No. 1.	System No. 2.	System No. 3.	System No. 4.
Aug. 7.....	0.65	0.40	0.35	0.32	0.30
Aug. 14.....	0.70	0.40	0.38	0.35	0.32
Aug. 21.....	0.72	0.27	0.40	0.20	0.26
Aug. 28.....	0.85	0.21	0.43	0.30	0.31
Sept. 4.....	0.72	0.22	0.25	0.20	0.20
Sept. 11.....	0.85	0.30	0.35	0.20	0.25
Sept. 18.....	0.48	0.30	0.23	0.20	0.18
Oct. 2.....	0.48	0.20	0.23	0.18	0.16
Oct. 15.....	0.68	0.20	0.23	0.20	0.16
Oct. 28.....	0.56	0.22	0.22	0.17	0.14
Nov. 15.....	—	—	—	—	0.12

In addition to the above, numerous other determinations have been made, but the ones given are typical.

The writer's opinion, based upon the above results, is that either System No. 3 or System No. 4, and probably System No. 1, would remove the iron from the water to a satisfactory degree. System No. 1, however, does not remove the carbon dioxide effectively, and the effluent from such a system in practice would have a greater corrosive action upon pipes than that from the other systems. A satisfactory plant in practice should reduce the iron to below 0.2 parts per million, and the carbon dioxide to at least 5.0 parts per million. System No. 2 does not satisfy these requirements. For the removal of iron only, systems Nos. 1, 3, and 4 would produce satisfactory effluents, and the comparative quality of the same would improve from No. 1 to No. 4. Apart from the corrosive action of the water, the relative merits of the three systems should be judged upon a cost basis.

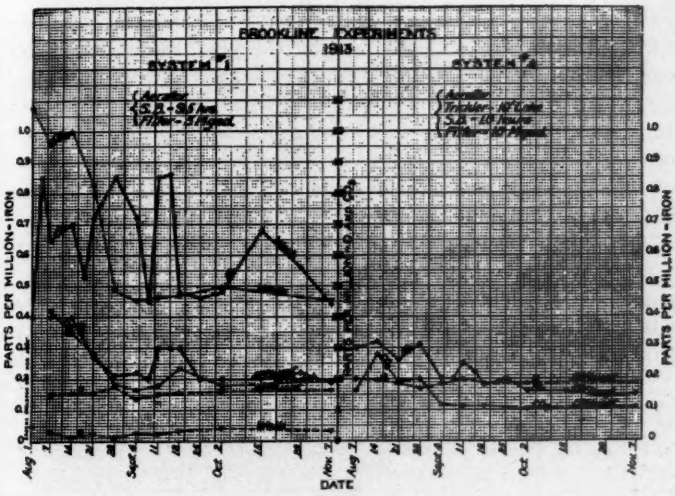


FIG. 2.

BROOKLINE EXPERIMENTS.

Comparative Efficiencies of System No. 1 (Aëration and Subsidence) and System No. 4 (Aëration and Contact).

The construction costs of the four systems in practice, including engineering, are estimated as follows:

COST OF DEFERRIZATION PLANT AND APPURTENANCES.

(Capacity, 8 000 000 gal. daily.)

System No. 1	$284 900
System No. 2	152 900
System No. 3	157 850
System No. 4	162 800

Apparently at Brookline, for deferrization and demanganization, it is not necessary to operate the tricklers submerged, and the iron and manganese in the effluent from Filter No. 4 decreased during the experiments until the end. It would be unwise, however, in view of the fact that the composition of the ground water,

supplied in part from beds irrigated with water pumped from the Charles River, varies greatly during the year, and because the complete removal of color is also desirable, not to provide means for partially submerging the coke if necessary. The experiments will be continued, but at this writing it seems as if the efficiency of deferrization by this method depended upon the accumulation of a film on the coke and the degree of aëration of the water, as shown by the dissolved oxygen.

The costs of operation with systems Nos. 1, 3, and 4 are estimated as follows. In estimating the cost of water by the different systems, we have assumed the capacity of the plant to be 8 000 000 gal. per diem and the average daily consumption to be 5 000 000 gal.

ANNUAL COST.

	System No. 1.	System No. 3.	System No. 4.
Fixed charges at 6 per cent....	$17 094 00	$9 471 00	$9 768 00
Fuel.....	1 343 00	1 712 00	2 080 00
Oil, waste, etc.....	100 00	100 00	100 00
Cleaning basins and flushing tricklers.....	100 00	100 00	100 00
Scraping sand filters.....	323 00	510 00	121 00
Three filter attendants.....	2 160 00	2 160 00	2 160 00
Superintendence, analyses, records, etc.....	1 200 00	1 200 00	1 200 00
Total cost of operation per annum.....	$22 320 00	$15 253 00	$15 529 00
Cost without fixed charges per million gallons.....	$2 86	$3 17	$3 16
Cost of water per million gallons	$12 24	$8 37	$8 51

That System No. 4 is to be preferred may be judged from the estimated cost of operation. This is influenced both by the higher construction cost of System No. 1 and the larger yield between scrapings of Filter No. 4. There was insufficient time before freezing weather to determine this latter factor exactly, as Filter No. 4 has not required scraping, but the following table will indicate the comparative estimated yields of the four systems.

System.	Average Yield between Scrapings. Million Gallons per Acre.
No. 1	347
No. 2	165
No. 3	220
No. 4	over 1 000

MIDDLEBORO EXPERIMENTS.

While the chief interfering substance at Cohasset is organic matter, at Middleboro it is manganese; both organic matter and manganese interfere at Brookline, but the small mass of iron increases the difficulty of deferrization.

Previous Experiments. During 1912 and previously experiments were made by the Massachusetts State Board of Health and others, and Mr. Clark tells me that they succeeded by intensive aëration, and filtration at a rate of from 7 000 000 to 10 000 000 gal. per acre per diem, in reducing the iron from 2.0 to 0.3 parts per million. The writer is unaware that the presence of manganese was considered as a factor in the problem. Upon being consulted by the water commissioners and fearing that manganese was present in the well water, the writer advised that the experiments be continued.

1913 Experiments. The experiments were made with the same filter which had been operated for the State Board of Health since October, 1912.

The experimental devices were arranged as follows:

1. A spray aërator discharging upon a trickler.

2. A trickler consisting of one barrel filled with a 2.5 ft. depth of 1 to 1½ in. broken stone.

3. A filter containing a depth of 26 in. of sand, having an effective size of 0.285 mm. and a uniformity coefficient of 2.3. This filter was operated at a rate of 10 million gallons a day, and had a depth of only 8 in. of water above the sand. It was provided with a rate controller and loss of head gages. The sand area was 2.5 ft.

Results of Experiments. This plant was started on January 18.

In the beginning the filter clogged rapidly. The iron, however, was being reduced on an average from 0.90 to 0.18 parts per million, as shown with other results in the following table.

AVERAGE RESULTS OF OPERATION, EXPERIMENTAL FILTERS, JANUARY 13 TO 31.

(Parts per Million.)

Determination.	Well Water.	Trickler Effluent.	Filter Effluent.
Color	55	29	13
Iron	0.90	0.60	0.18
Carbon dioxide	33.9	16.4	18.5
Dissolved oxygen	4.81	8.83	6.81

By February 1 the filter had been scraped four times and a subsiding basin having a capacity equivalent to 1.5 hr. flow was placed between trickler and filter. The trickler which had been operating half submerged was raised so as to operate non-submerged. The average results after this change were as follows:

RESULTS OF OPERATION, EXPERIMENTAL FILTER, FEBRUARY 1 TO FEBRUARY 11.

(Parts per Million.)

Determination.	Well Water.	Trickler Effluent.	Filter Effluent.
Color	30	22	11
Iron	0.76	0.42	0.13
Manganese	0.50	0.40	0.30
Carbon dioxide	45.6	18.5	13.2
Dissolved oxygen	2.56	9.55	9.13

It was apparent during this period that the removal of iron was satisfactory; the filter still clogged rapidly (about every three days) and manganese passed through both trickler and filter and appeared as a black deposit of oxide, or manganese rust, in the little ditch which received the filter effluent. It was therefore decided to increase the contact, to remove the manganese, and

on February 11 another barrel filled with coke was added to the trickler equipment. The new arrangement was put in service on February 4. The results up to February 19 were as follows:

RESULTS OF OPERATION, EXPERIMENTAL FILTER, FEBRUARY 4 TO FEBRUARY 19.

(Parts per Million.)

Determination.	Well Water.	Trickler Effluent.	Filter Effluent.
Color	39	33	13
Iron	0.84	0.46	0.23
Manganese	0.93	0.99	0.86
Carbon dioxide	44.2	5.4	6.7
Dissolved oxygen	2.74	10.45	8.10

The filter effluent was still turbid with manganese, although by February 15 the reduction of dissolved oxygen in the filter was noticeably increased and scum on top of filter was appreciably darker. The period between scrapings had lengthened but slightly. It was therefore decided, chiefly in order to hurry the experiment, to increase the contact period by filling the subsiding basin with coke. This was done on February 20. The results of this change were as follows:

RESULTS OF OPERATION, EXPERIMENTAL FILTER, FEBRUARY 21 TO MARCH 14.

Determination.	Well Water.	Spray Aërator.	Trickler Effluent.	Basin Effluent.	Filter Effluent.
Color	52		28	24	13
Turbidity	16		6	5	5
Iron	1.35		1.5	0.35	0.21
Manganese	0.68		0.79	0.79	0.60
Carbon dioxide	48	40	5	4.5	5.5
Dissolved oxygen	3.30	—	10.70	10.32	9.28

During this period some oxidation was taking place in the filter, but the turbidity of the effluent decreased; the manganese

began to accumulate on the surface of the sand, and the periods between scrapings increased somewhat. More contact was evidently necessary, but as a half hour's contact with the submerged coke did not seem to effect any removal of manganese, the height of the trickler was increased 50 per cent. by placing another barrel filled with coke on top of the others. The total depth of trickler was now 6.7 ft. and there was submerged contact in addition. The spray nozzle discharged on this coke from a height of 20 in. The filtration through the trickler was increased to 75 million gallons a day. The immediate results of this change on the dissolved gases were as follows:

RESULTS OF OPERATION, EXPERIMENTAL FILTER, BEFORE AND AFTER CHANGES, MARCH 14.

(Parts per Million.)

Determination.	Well Water.		Trickler Effluent.		Basin Effluent.		Filter Effluent.	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.
Carbon dioxide...	43.5	38.7	5.7	4.5	6.6	5.5	6.5	10.5
Dissolved oxygen.	3.01	3.01	9.75	10.82	9.50	9.84	9.5	9.89

RESULTS OF OPERATION, EXPERIMENTAL FILTER, MARCH 27 AND APRIL 23, 1913.

(Parts per Million.)

Determination.	Well Water.		Trickler Effluent.		Basin Effluent.		Filter Effluent.	
	Mar. 27.	Apr. 23.	Mar. 27.	Apr. 23.	Mar. 27.	Apr. 23.	Mar. 27.	Apr. 23.
Color.....	45	45	40	38	12	10	10	10
Turbidity.....	3	2	5	5	2	2	1	1
Iron.....	1.2	0.9	1.9	1.8	0.35	0.25	0.15	0.2
Manganese.....	0.75	0.72	0.95	0.9	0.75	0.55	0.38	0.25
Carbon dioxide...	44	48	5.0	5.0	5.5	5.3	5.0	5.0
Dissolved oxygen.	3.50	4.21	11.07	11.42	10.83	11.51	10.91	11.26

The plant ran without change until June 6. Immediately the operation of the filter began to improve, the period between rakings increased to double or more, and the filter was not scraped again. Simple raking restored the sand layer to efficient operation. On March 27 and April 23 the results were as shown by the preceding table.

The results for April 23 were so satisfactory that analyses were discontinued until June 6, when the experiment was stopped and samples of trickler, basin, and filter effluents were collected for analysis; the results were as follows:

RESULTS OF OPERATION, EXPERIMENTAL PLANT, JUNE 6, 1913.

(Parts per Million.)

Determination.	Trickler Effluent.	Basin Effluent.	Filter Effluent.
Color	15	10	4
Turbidity	8	5	1
Iron	0.90	0.40	0.20
Manganese	0.95	0.45	0.20
Carbon dioxide	6.0	4.0	3.0

These results confirmed the previous ones and exemplified the increased efficiency due to the accumulation of coatings on the materials in the trickler and subsiding basin.

Character of Coatings. The trickler was dismantled and samples of dried coatings from different points were analyzed with the results shown in Table VI.

TABLE VI.

SHOWING COMPOSITION OF COATINGS FROM DIFFERENT POINTS.

Source.	Top of Trickler.	Bottom of Trickler.	Bottom of Basin.	Surface of Filter.
	Per Cent.			
Iron	29.16	21.56	40.32	8.51
Manganese	1.82	7.69	3.41	10.15
Aluminum	5.19	3.39	2.54	6.78

This table shows where the work was done. The removal of the iron began at once and was nearly complete except for the final straining before the filter was reached.

The demanganization process began in the lower part of the trickler, but most of the manganese passed through the subsiding basin and was removed by the filters. Earlier in the experiments the manganese penetrated and discolored the filter sand; later the accumulation was largely restricted to the surface and the sand became clean again. At Brookline the sand is still discolored with manganese.

The precipitation of aluminum is interesting, and the writer is not aware that it has been noted before. It is evidently not so difficult to remove as manganese, but more difficult than iron. Strangely enough, the molecular weights of the oxides vary inversely with the speed of precipitation; that is, the metal which forms the heaviest oxide precipitates easiest. Aluminum, however, requires no oxidation, while the oxidation of iron and manganese must precede their coagulation and precipitation.

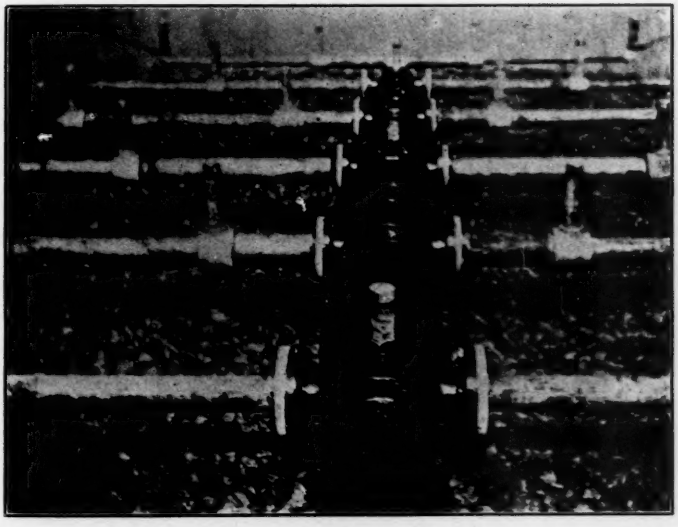
MIDDLEBORO PURIFICATION PLANT.

The design of the Middleboro plant was made during the experiments, and the plant was built during the summer of 1913; the contractor for the main structures was the Briggs Engineering and Construction Company, of Providence, and the low-lift pump was supplied by the Power Equipment Company, of Boston. The details of the design and construction were worked out and supervised by Mr. G. A. Sampson, with T. F. Dorsey as resident engineer. The plant consists of the following parts:

A DeLaval steam-turbine-driven, centrifugal pump, having a capacity of 1 000 000 gal. per day. This pump takes water from the present well and discharges it on top of the pile of coke, — a so-called trickler, — through a number of sprinkling nozzles.

A trickler built of concrete, 30 ft. in diameter outside measurements, and containing 10 ft. of coarse coke supported upon a concrete grill work, above the true bottom. The water from the trickler falls upon its true bottom and flows through a pipe into the settling basin.

MIDDLEBORO.
Showing Aërator in Operation.



MIDDLEBORO.
Aërator Piping.

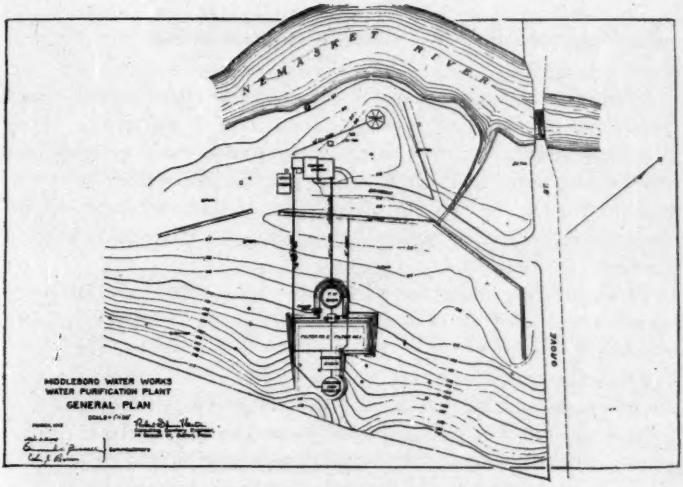


FIG. 3. *MIDDLEBORO DEFERRIZATION PLANT.
General Plan.

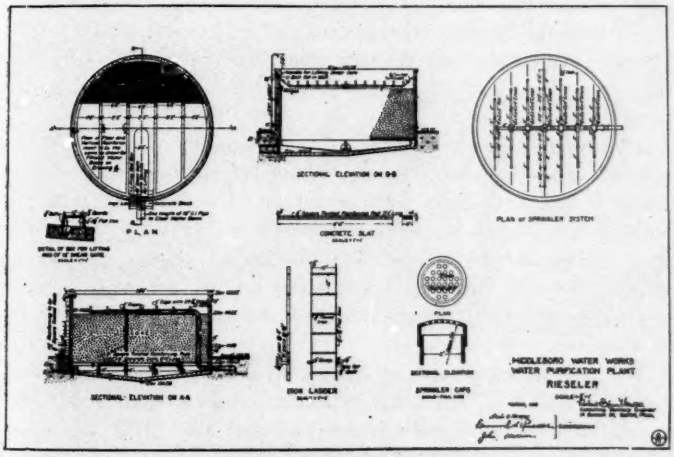


FIG. 4. *MIDDLEBORO DEFERRIZATION PLANT.
Coke Rieseler or Trickler with Aërator.

The settling basin is built of concrete and has a capacity of 40 000 gal. It is covered with a concrete roof and earth to prevent freezing.

From the settling basin the water flows into the two compartments of the filter, having a total area of 0.1 acre. These filters are simply concrete basins with groined roofs, covered like the settling basin with earth to prevent the freezing of the water in winter. On the bottom of the filter is laid tile under-drains covered with 12 in. of graded gravel, supporting in turn 3 ft. of medium sized sand.

From the two filters the water flows into a regulator house in which are located all of the valves and gages for operating and regulating the filters.

From the regulator house the water flows into a filtered water basin which holds 42 000 gal. This is large enough to enable the pumps and filters to operate regularly and to supply the hydrants during ordinary fires. For fire purposes this supply is at the rate of at least 1 000 000 gal. in twenty-four hours, or twice this amount during one hour. The present consumption is about 335 000 gal. per day; and the maximum consumption for any one day has been 873 000.

Of these various parts the aërator and trickler are alone worthy of special comment, for although the filters embody some special features, these may be readily apprehended by inspecting the plates.

Aërator and Trickler. The aërator consists of a system of piping connecting the discharge from the low-lift pump with thirty-seven 2-in. nipples. On each nipple is screwed a cap drilled with twenty-four $\frac{3}{16}$-in. holes and pressed to make the upper surface convex and the axes of the holes radial. These sprays discharge upwards, discharging the water on the surface of a layer of coarse coke, 10 ft. deep, contained in a concrete tower 28.3 ft. in diameter.

The coke is supported upon 2-in. by 6-in. reinforced concrete beams spaced 2 in. apart and supported upon a beam 6 in. wide, around the inside of the trickler wall and also upon four cross walls, 6 in. wide, resting on the floor.

The floor slopes to a channel leading to the 18-in. cast-iron

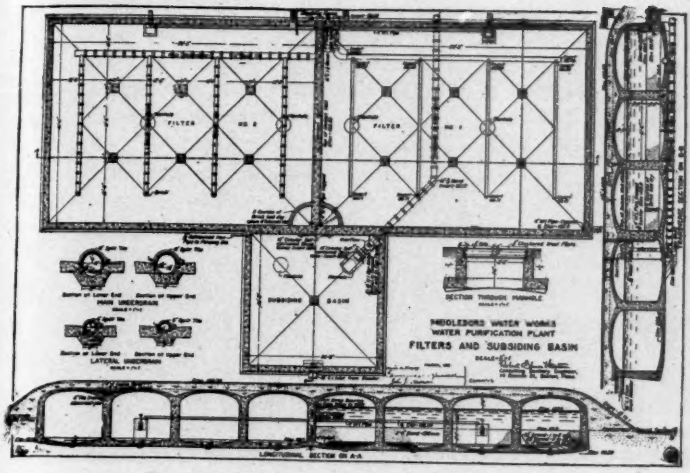


FIG. 5. MIDDLEBORO DEFERRIZATION PLANT.
Filters and Subsiding Basin.

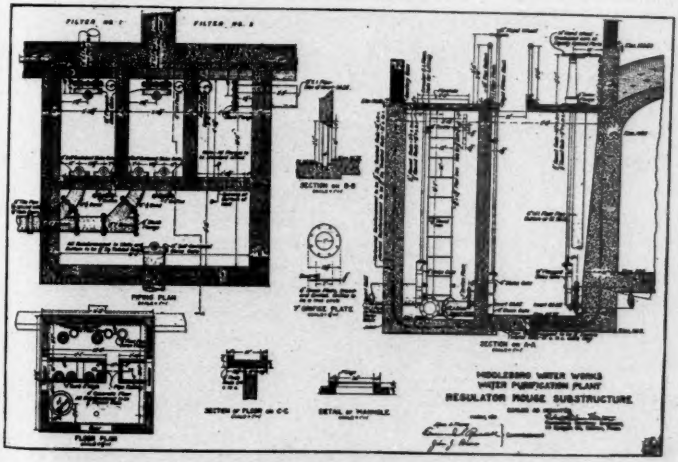


FIG. 6. MIDDLEBORO DEFERRIZATION PLANT.
Regulator House Substructure.

pipe which connects with the subsiding basins and filters. A shear gate provides for the closing of this outlet, when the trickler may be filled; then the valve may be opened quickly and the excess of accumulation in the coke flushed out, through the subsiding basin and into the drain. It is not expected that flushing will be required oftener than once a year.

Filters and Appurtenances. The two filters have no doors and runways, but special sand boxes have been designed, into which the sand removed by scraping is dumped and washed out into bins placed outside the filter. The sand used in the filters had an effective size of 0.31 mm. and a uniformity coefficient of 1.80. It was a natural bank sand which did not require washing.

The regulating devices are of the orifice type and indicating rate and loss of head gages are provided for each filter.

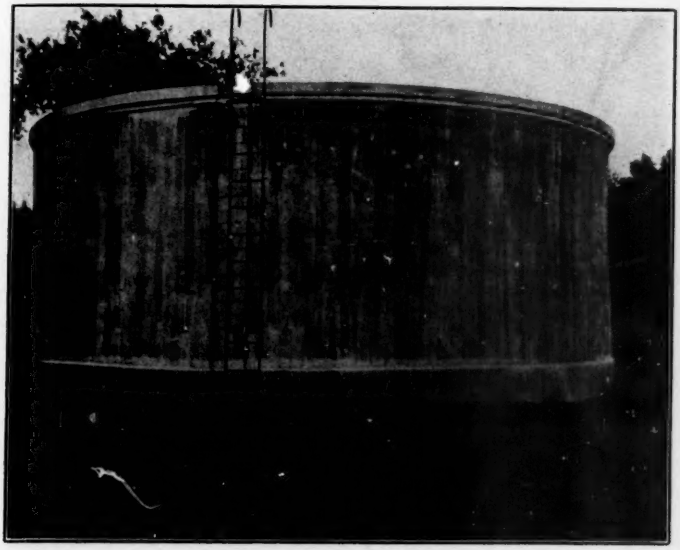
Cost. The complete plant has cost about $18 000, including engineering.

Results. The filters started on September 26, 1913. They had been raked twice and scraped once prior to January 12, 1914. The yield for this first run was 40 million gallons, or 400 million gallons per acre. The filters have been in operation so short a time that the effluent varies in quality considerably, particularly just before and after scraping or raking the filter. The average results are as follows:

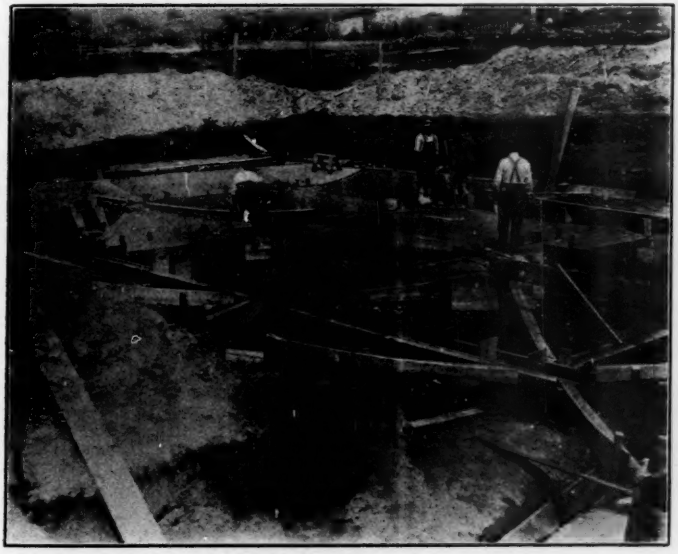
AVERAGE RESULTS OF OPERATION, MIDDLEBORO, FIRST RUN, SEPTEMBER 26, 1913, TO JANUARY, 12, 1914.
(Parts per Million.)

Determination.	Well.	Settling Basin Effluent.	Filter Effluent.
Color	48	22	5
Turbidity	5	3	1
Iron	1.62	0.46	0.17
Manganese	0.67	0.36	0.27
Hardness*	27.3	——	23.4
Oxygen consumed	1.79	1.53	1.05
Carbon dioxide*	41.0	4.2	4.6
Dissolved oxygen*	2.95	10.20	9.55

* One determination.



MIDDLEBORO.
Rieseler or Trickler.



MIDDLEBORO.
Placing Concrete in Filter Bottom.

The above results bear out the conclusions of the experiments very well, although the manganese had not been reduced as low as it was later, on January 22, when it was reduced from 0.85 part per million in the well water to 0.10 in the filter effluent. After scraping, the iron increased to .35 part in the filter effluent, but the latest result, by the State Board of Health, on February 4, shows it to be 0.18 part per million, — all that could be desired.

Should the organic matter in the well water increase, the trickler may be arranged to be operated partly submerged. So far this has not been necessary, although the "oxygen consumed" is now considerably higher than during the experiments. The removal of the carbon dioxide and the practical saturation of the water with oxygen are worthy of notice; also the great share of the work borne by the trickler, thereby greatly lessening the cost of filter operation.

GENERAL CONSIDERATIONS.

In this paper have been given the results of experience with three waters containing iron and manganese, one of which could not be aërated to saturation without causing some of the iron and color to escape removal, and one of which required complete oxidation to effect a satisfactory removal of manganese. The third water demands complete aëration and long contact as well, and contingencies may arise when this contact should be effected with the material submerged.

Other things being equal, it is well to remove the carbon dioxide as completely as practicable in order to prevent subsequent corrosive action of the water upon the distribution, consequently aëration and contact in a trickler should be employed as far as possible, and submerged contact when this method fails.

Naturally, the choice of methods depends upon the character of the untreated water, and if the writer has made it plain that not only do different supplies vary, but that even the water from the same well may require a varying treatment, he will feel repaid.

Regarding the choice of filter, it may be stated that properly treated water can be filtered either through slow or rapid filters, with good success. The high rates possible with a sand filter, and the infrequency of cleaning when the pretreatment is ade-

quate, usually makes it more economical than the mechanical filter; furthermore, when manganese is present, it undoubtedly gives more uniform results.

DISCUSSION.

MR. ALLEN HAZEN. I first came in contact with this iron removal problem about twenty years ago, when I saw some of the German works that Mr. Weston has described. Afterward I had something to do with some of the earlier attempts to introduce these methods in this country. If I am not mistaken, the earliest plants in which iron was removed from ground waters were on Long Island and along the New Jersey coast. The waters in these two localities are practically the same chemically, and the iron was removed very easily indeed, in the way that Mr. Weston mentioned in connection with Marblehead. It was simply necessary to aërate and filter the water. It did not take a great deal of aëration, and almost anything which could be called a filter would take out the coarsely precipitated iron. It may be that the ease with which the iron was removed in those first cases served to make us think that the problem was easier than it really was. The difficulties were found later when other kinds of waters were tackled.

The plant at Superior, Wis., which Mr. Weston has mentioned, and where he struggled with the problem in an experimental way through some months, was one of the early ones which showed difficulties. The water carried a moderate amount of iron, and after aëration and filtration the iron was not separated in the way that it was found to separate in New Jersey and Long Island. A plant was built, however, upon these same general lines, with some modifications suggested by Mr. Weston's experiments, and it has operated with success up to the present time. The removal of the iron was not as complete, however, as in the other cases. The New Jersey and the Long Island plants removed every trace of iron. The Superior plant was not capable of doing this, and the effluent always carried an appreciable amount. The iron which was left seemed to be so firmly combined with organic matter that it caused no practical trouble, and from the standpoint

of the water company and of the water takers the plant has been eminently successful.

I saw the plant in Superior two weeks ago, and it is interesting to note that in the course of the fifteen years that the plant has been in operation the iron has gradually decreased in the well-water supply so that at present there is only about a third as much as there was when the plant was first put in operation.

Mr. HARRY W. CLARK (*by letter*). — In this connection I can say that experiments upon the removal of iron from ground waters in Massachusetts began to be made under my charge about eighteen years ago, and the report of the Massachusetts State Board of Health for 1899 contains an article by me, entitled "The Occurrence of Iron in Ground Waters, and Experiments upon Methods of Removal." These experiments showed that aëration and sand filtration at high rates were entirely successful in such removal with the majority of the waters experimented with at that time, but from one of them, the then Provincetown supply, iron could not be successfully removed by the treatments tried. The interference of carbonic acid and organic matter was discussed in that paper, but the influence of manganese was not then recognized. However, at the time of the experiments carried on at Middleboro by this Board in 1911 and 1912, this factor of interference by manganese was well understood and our experiments, as stated by Mr. Weston, were successful in freeing the Middleboro water from iron and cloudiness. During the past eight years numerous determinations of the amounts of manganese in ground water supplies have been made in these laboratories and its importance in connection with water and water purification noted.

PROPER CHARGE FOR FIRE PROTECTION SERVICE.

TOPICAL DISCUSSION.

[*January 14, 1914.*]

MR. FRANCIS T. KEMBLE.* I would like to bring up the matter of private fire lines, with an idea of seeing what our members think is a proper charge for such service, what should be considered an adequate ready-to-serve charge. The private fire line situation at the present time, when architects and underwriters are asking for mains and double mains, capable of delivering large volumes of water, to be carried into buildings, is a pretty serious one.

We have not only to be ready to furnish a good deal of water, but we have to run a considerable risk if anything happens to these lines, and perhaps takes the pressure off a main. We had one case a year ago where a building used as a plant for making moving pictures went up in a hurry. There was a 4-in. line running in there, supplied from a small main, the wall came down on the gate so that we could not get at it, and the line running free in the building took the pressure off our main.

It seems to me that a water company ought to make a pretty good readiness-to-serve charge.

THE PRESIDENT. This is a subject which has been discussed for many years, and has been a troublesome one to all waterworks superintendents. Many of them think that fire service pipes running into a building are often a great menace to the water supply, especially in case of a conflagration where buildings will come down, and where on account of the narrow streets it is impossible to get in to shut the water off. I hope that there will be a free discussion of this interesting subject.

MR. FRANK E. MERRILL.† This is a subject which interests me at the present time, because we have an application pending

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* Secretary New Rochelle Water Company, New Rochelle, N. Y.
† Water Commissioner, Somerville, Mass.

for a 6-in. fire service off a 6-in. dead-end main. I should like to ask the members who are interested in these matters what they would do with such an application if it should come to them; not only as regards the charge for service, but also as to granting a request for so large a service as 6-in. under the conditions existing?

MR. KEMBLE. The suggestion is made to me that in such a case you put a meter on, but that does not mean anything really, because they might never use any water to speak of. I contend that you ought to have a pretty good ready-to-serve charge.

MR. CHARLES H. TUTTLE.* The Bristol and Warren Water Works, which is a private corporation, has contracts with the towns which call for the furnishing of water for fire purposes free. Whenever application is made for a fire service we insist upon a meter going on to the service. For all water used through that meter we get our regular rates, but what is used for the actual putting out of fires is furnished free. The fire services are put in at the expense of the person making the application, and the company is at no expense in the matter. We put it in and charge the actual cost plus a reasonable percentage for overseeing the job.

MR. H. O. LACOUNT.† Mr. President, whenever I have occasion to think along this line I am very much impressed with the fact, which I think is being shown, that one of the best ways to prevent a conflagration is to very freely supply fire protective equipments with water, and to do that we must have the fire service connection. Now I would not advocate putting in a fire service connection larger than the street main, certainly, and I think that in many cases we do not need to have a pipe as large as the street main. I, however, think we can go too far the other way, and have our sizes too small to do any real effective work, considering the amount of protection which is to be called for at the other end of the fire service connection.

The matter has been discussed a great many times with reference to the question of the size of the connection. That from an engineering standpoint is a very interesting study. I think that in all of this work good sense should prevail, and that we ought to

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* Superintendent Bristol and Warren Water Works, Bristol, R. I.

† Engineer and Assistant Secretary, Inspection Department, Associated Factory Mutual Fire Assurance Companies.

lay out our service connections not only with reference to the size, but to location, so that they will be least liable to be seriously crippled in case of a falling wall. I believe that much could be done along that line in the way of good engineering and good horse sense in placing our controlling valves on these fire service connections.

I appreciate that what I am saying is not with direct reference to the question that has been asked, and that is with reference to the charge. No doubt there are two sides to the question, but if we overdo the charge feature we at the same time will cripple the efficiency of our fire protection, because beyond a certain amount you penalize what many people, at least, believe is a good thing, and especially a good thing with reference to the protection of a congested area. Personally I am looking for the time when fire protection will be much more mandatory than it is at the present time, with purely the point of view of preventing these serious hazards to our congested areas which now and then do come to a head in the form of conflagrations. Just as soon as private fire protective equipments become in any section mandatory, there of course will be the necessity of securing an adequate water supply, and all these other questions will then be raised again as to what is the proper size of connection, what the proper charge, etc.

I have no doubt that some charge is reasonable, but from the tone of voice in which the question was asked I feel that the charge which, perhaps, the gentleman would advocate would be excessive, according to my view of the matter. I do not think that I am ready offhand to suggest what the charge should be in any given case, without having a chance to study its particular conditions, because I believe thoroughly that conditions will alter the case. Not only from the standpoint of good protection, — good engineering with a view to adequate protection, — but from the standpoint of what is fair to be paid for these privileges, it will be a matter of very considerate study to get at that one best opinion and best solution of the problem which all fair-minded people no doubt are striving to reach. But do not put in fire protection and expect that without the supply it will give a good account of itself, because you must have the water; and I fancy that even with an

occasional broken fire service connection we will extinguish our fires in the long run with much less water than we will in the other way, which is through hose streams at a distance and under the most unfavorable conditions which you could well imagine. If you apply your water promptly and directly at the seat of the fire you will use the least water and have the least fire loss. Therefore, favor the private automatic sprinkler equipment and do not tax it unreasonably.

MR. R. S. WESTON.* It might be of interest to the gentleman who asked the question to read Mr. George G. Earle's† paper describing the method of charging for water used at New Orleans. The charges for water itself are uniform to all consumers, but the charge for the use of the service — that is, the readiness-to-serve charge — varies with the size of the service. That is to say, a 6-in. service would cost much more per annum than a ¾-in. service. I believe there was also some extra charge to cover the cost to users of special fire protection. I think one in considering charges for fire protection should bear in mind that the cost of supplying fire service in the case of small works is very often 90 per cent. of the total cost of supplying water; and it would seem as if this fact would be a sufficient reason for compelling those who benefit by the costly provision for fire service to pay something like their just share of the cost of supplying water.

MR. CHARLES W. SHERMAN.‡ I do not feel ready to offer any suggestion as to the actual charge, but it seems to me that some combination of the suggestions that have been made by Mr. Lacount and two or three of the preceding speakers might, perhaps, serve as a basis for workir g out such a charge. It does not seem to me that there should be any charge for the water actually used for extinguishing fires. I believe that fire service pipes should be controlled by suitable meters; and that water used for any other purpose than extinguishing fires should be charged for. I believe with Mr. Lacount that the fire service pipe should be of sufficient size to be of value if a fire actually does occur. I think that his suggestion as to the location of the controlling valve

* Consulting Sanitary Engineer, Boston, Mass.
† Proc. A. W. W. Assoc. 1911, p. 173.
‡ Assistant Engineer, Metcalf & Eddy, Boston, Mass.

might, perhaps, be carried a little further and include the installation of additional main line valves each side of the branch, if such are not already in existence, and that it would not, perhaps, be unreasonable, in some cases at least, if the cost of those additional main line valves were figured in as a part of the installation cost of the private fire line.

Whatever charge there may be for fire protection should, it seems to me, be a readiness-to-serve charge. How much that should be is something for each works to figure out in view of the local situation; but obviously it should not be so large as to hinder the putting in of such a service as will do the work. Whether a charge made up by including the whole cost of installation, including additional main line valves, and a small annual readiness-to-serve charge, would not work out equitably, is the suggestion I have in mind.

MR. PATRICK GEAR.* This subject is one in which we are very much interested in the city of Holyoke. In our report for the year 1913, which is not ready for publication, there is a suggestion that we investigate the matter of charging the manufacturers for fire protection in their plants, where they have water pressure on sprinkler heads at all times, and for which they do not pay a cent to the water department. If the manufacturers get their insurance rates from 20 to 30 per cent. cheaper than formerly, it seems to me that they should be willing to pay the water department some revenue for supplying this water pressure.

If you should talk with any manufacturer or any of his men, they will tell you that they do not use any water; but if we have an occasion to shut off the water for two or three hours to make some repairs, then a man is needed to shut and open the dampers, for they will not operate unless the pressure is there. This is another case of where the water department is furnishing water pressure and receiving nothing for so doing.

I would like to hear from some of the other superintendents with reference to this matter, who meet with the same conditions as we do, to learn whether or not they have a fixed rate or charge for same.

* Superintendent Water Works, Holyoke, Mass.

MR. ROBERT J. THOMAS.* In Lowell we do not charge anything for the water used for the extinguishment of fires, but we do insist on a meter being placed upon the services, so that we may be able to charge for water used for other than fire purposes. That is about the only regulation we have, excepting that we will not tolerate any connection between the city pipes and the pipes of private water systems.

Out West in many places they do charge for fire services. I think in Indianapolis and several of the large cities they begin with a 4-in. pipe, charging, say, $25, $50 for a 6-in., $75 for an 8-in., $100 for a 12-in. In some cities they restrict the size to 6 in., and in many places they will not allow a larger connection than 4 in. The charge for fire services, take it the country over, but especially in New England, is very moderate. I believe that all water works, public or privately owned, should insist that they be protected, and no water used for other than fire purposes unless it is charged for.

MR. CARLETON E. DAVIS.† It is customary in Philadelphia to furnish fire protection supply as distinct from domestic supply without charge. A bond, however, of $400 is required, stipulating that the water shall not be used for other than fire purposes. On fire lines there is generally a by-pass line on which is set a meter one inch or thereabouts in size, which is supposed to indicate when water is used for other than fire purposes. Sometimes this by-pass meter works successfully and sometimes it does not.

We found recently an interesting case where one of the prominent newspapers in the city had a 4-in. fire line. They were under the customary bond not to use the water for anything but fire purposes. We found they had a 2-in. connection from that fire line supplying water to the type foundry. Of course they objected seriously when a charge was made on the schedule basis for the size of the fire line.

The underwriters in Philadelphia have recently proposed to use the high pressure fire system to furnish water for sprinklers. The city has two high-pressure systems, one covering a portion of the mill district and one covering a portion of the business

*Superintendent of Water Works, Lowell, Mass.
†Chief Engineer, Bureau of Water, Philadelphia, Pa.

district. The domestic pressure in the bulk of these territories is low, very rarely going above 50 lb., and often much less.

The underwriters have suggested maintaining a permanent high pressure on the fire-line system and connecting it with the sprinklers. Objections have been offered to this proposal. One serious objection, which is of the same nature as that suggested by Mr. Thomas, is that one of these high-pressure systems is supplied with raw water from the Delaware River. Of course it would be difficult to keep the two systems of pipes inside the buildings distinct. The temptation to draw from the high-pressure lines for other than fire purposes would probably be too strong in many instances.

An objection has been raised as to whether the sprinkler heads would stand the high pressure which would be put upon them when the system is in use in time of fires. The underwriters have recently conducted some experiments to determine the relative efficiency of streams under different heads. The results of those tests are not yet available.

MR. JOHN DOYLE.* In Worcester the Water Department requires all water to be metered, where there are underground connections. For instance, if the connection is 50 or 60 or 100 ft. inside of the property line of the manufacturing plant there is installed a detector meter. Where we put in fire pipes and the building abuts on the street line, we go in with both connections. We have a high and low system in Worcester in the business section, and we bring both lines inside the property line into the building proper, and the sprinkler system is connected there, both lines being brought together, and we install valves and a small meter which acts as a sort of detector for small streams, where there is any liability of small streams being used off the sprinkler system through the building. But in all cases the department requires that detector meters be put on all underground lines. So the liability of any inside connection being made with the system is rather remote, because with our system of a small detector meter, as we call it, put upon the alarm system inside the building, it will show when any water is being used. So far as I know, there is no charge for any water used on the sprinkler system.

* General Foreman, Water Department, Worcester, Mass.

unless it might come about that there might be an excessive amount used. We also have an inspector who visits the fire systems once a month and makes a record of his inspection for the water commissioner, and any excessive use of water is looked after very closely. Furthermore, in all cases we seal the valves inside the buildings, and if the factory owner or manufacturer has occasion to break the seal on any of those valves, he is supposed to notify the water department immediately that he has done it, and our inspector immediately goes there after receiving the notice and reseals the valve. So far as I know, there has no charge ever been made for water used for fire purposes in any building where there is a sprinkler system.

MR. WILLIAM SULLIVAN. I should like to add one query to those which have been put. My question is, whether a charge is ever made for the amount of water which is used in the inspection of private supplies, these hydrants and standpipes, etc. Periodically the insurance inspectors come around and test the systems and use considerable water, so I want to add that query to the others.

METHODS USED TO LOCATE HIDDEN LEAKS IN UNDERGROUND PIPES, WITH SPECIAL REFERENCE TO PIPES WHOSE EXACT LOCATION IS UNKNOWN.

TOPICAL DISCUSSION.

[*January 14, 1914.*]

MR. PATRICK GEAR.* We are trying at the present time in Holyoke to account for an unusually high consumption in one of our residential sections.

The average daily consumption in one section of the city which has 6 000 people is 58 gal. per day per capita, which we are satisfied is a fair and proper amount; but in a similar section containing 5 000 people, the daily per capita consumption is 150 gal., which we feel is altogether too large.

An inspection of the fixtures in this district showed them to be in very good condition, and there is no indication on the surface of any leak, nor is there any lack of pressure in any particular locality.

We became satisfied early in January that some condition existed which should be discovered and rectified if possible, and made a few tests in the hours of the night, when the consumption would be smallest. Our method was to shut all the gates in one or two blocks in the section under investigation and then meter the water used in the blocks shut off, feeding through a fire hose with meter attached from a hydrant outside the section to another hydrant inside. We found various sections to be using at the rate of 28, 18, 14, and 12 gal. per day per capita, perhaps about one third of the area of the whole district.

Owing to the cold nights and consequent freezing of the hose, we decided to postpone further tests of this kind till more suitable weather conditions prevailed if the cause of the high rate was not discovered before then, and meantime we are having tested the 16-in. meter at the reservoir, from which this supply is drawn.

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* Superintendent Water Works, Holyoke, Mass.

MR. GEAR (*by letter*). The test of the meter by the National Meter Company was reported as satisfactory. By the time we received this report from the meter company, the ground was frozen pretty deep and we did not care to run any extra chances turning on high service in cold weather, and so we delayed any move in this direction until spring.

Meanwhile our engineer computed how much storage we ought to have in the reservoir, on the basis of collecting the same as on the Tucker Brook watershed for 1913 and drawing out from the reservoir the amount shown by the meter, and found we had in storage about 200 million gallons more than the computation would show.

We cut the pipe and disconnected the meter at the throat, and found a piece of 2-in. plank, seven inches square, which forced twice as much water through the registering part of meter as was actually used. This was the cause of all our trouble. We found no leaks and everything is all right.

USE OF THE FORCE PUMP IN CLEANING SERVICE PIPES.

[*February 11, 1914.*]

TOPICAL DISCUSSION.

MR. GEORGE H. FINNERAN.* Those of us who have to do with the distribution of water are familiar with the complaints, "No force," "Partial stoppage," "Complete stoppage," etc. Where lead pipes are used to supply the consumers, the trouble is usually located at the corporation cock or tap, where rust or corrosion accumulates. It comes in from the main and lodges in the cock. Now the usual method of relieving a situation like that is to dig down to the cock and clear it out, and as a rule the results are satisfactory. But that is a rather costly operation in large cities where pavements are expensive, and the public convenience also suffers. However, I think we have devised something that practically solves the problem.

It is a high pressure, lever-handle hand pump, — a small affair that can be carried around by a plumber and his helper. We make a connection with the service pipe just inside the cellar wall, usually at the stop-cock. We use the stop-cock to control the water from the street. Previously to connecting the pump to the supply pipe we insert in the supply pipe a wad of paper. That is the essence of the operation. In fact, it is the secret of its success. This wad of paper completely fills the interior of the supply pipe. We then couple the pump to the supply pipe and are ready to proceed. There is one other thing necessary, — we have to supply water to the pump. It is a pressure pump, and while it will draft a little, yet you get better results by feeding it with an ordinary force pump which drafts from a pail of water. Of course the supply pipe is filled with water from the pump to the street, and any extra water that is pumped in makes a pressure and drives the wad of paper out towards the corporation

* Assistant Superintendent Water Service, Boston, Mass.

cock until it meets the obstruction. There may be a very small water-way through the obstruction, perhaps the size of a pinhole or perhaps larger, but the wad of paper is forced against the rust or corrosion, and completely dams up the little waterway, thus making a complete stoppage. A few more strokes of the pump and sufficient pressure is accumulated to break down the entire obstruction and carry the rust or corrosion and the wad of paper into the main and thoroughly clear the cock.

The removal of stoppages in this way has proved very satisfactory. I have in mind a case where it required seventeen minutes to fill a pail or a vessel that contained one cubic foot of water, and after the clearance the same amount of water was drawn in twenty-three seconds. The improvement was well worth the effort.

We also have found it efficient in clearing out iron pipes inside of buildings. It is desirable to have an open end to your iron pipe. The wad of paper is inserted in the pipe and the pump applied. As the wad proceeds it scours the walls of the pipe and carries the rust with it, and we get quite an accumulation. We save it sometimes and weigh it to see how much there is. In one case recently we cleared $3\frac{1}{2}$ lb. of iron rust out of 10 ft. of 1-in. pipe.

At first, while we were experimenting, we simply used ordinary newspaper for the wad or the pellet, but we didn't think it advisable to continue using that. Sometimes it was a "yellow journal," and as a general proposition it was not very sanitary, so now we use good quality tissue paper. It is compressed very hard, but the moment it gets out into the main it unfolds and dissolves and is carried away somewhere — through a hydrant, let us hope. It is a simple operation, the prime factor of which is the little pellet which for the time being creates a complete stoppage, where prior to the operation there was only a partial stoppage.

MR. FRANK L. FULLER. I should like to ask how this works where there is a hard corrosion, such as we sometimes see when we take out old iron service pipes. I should not suppose that could be removed, or that a wad of paper could be forced through it.

MR. FINNERAN. Oh, yes; it will take out the very hardest mass of corrosion. We have cleared cocks where, without this operation, it would have been necessary to take an instrument and drive it out. Of course the water helps to dissolve and soften the corrosion. This pump, by the way, has produced a pressure up to 1 000 lb., although we have never used as much. I think that the ordinary lead pipe you find in the street would not stand such a pressure. As a rule we do not find it necessary to use over 150 to 200 lb. pressure. We used to carry a gage on the pump at first, and I think the very highest pressure we employed was 300 lb. Some of our stoppages were corkers; they were almost as hard as the brass that the cock is made of.

MR. T. G. HAZARD, JR. I would like to ask the gentleman what would happen in case the service pipe from the main to the cellar was decidedly smaller than the pipe leading from the cellar into the house; that is, if the pipe where you made your connection with the pump was one inch and the service in the street was, say, half an inch? Would there be any danger of the paper pellet stopping up the pipe entirely at the curb cock?

MR. FINNERAN. The wad of paper would soften and accommodate itself to the smaller area. That is, it becomes plastic after immersion. Of course at first the paper is very hard, but the longer it remains in the water the softer it becomes, and it accommodates itself to the shape of the pipe and the condition that it meets.

MR. GEORGE A. KING. As I understand it, this wad of paper simply stops up the hole entirely, so that you can get the pressure of the pump to take effect. The paper doesn't clean the pipe, but it is the pressure which cleans the pipe.

THE PRESIDENT. No; the paper cleans the pipe.

MR. KING. Could not we clean it without the paper, if we had the force?

THE PRESIDENT. There are a number of ways of cleaning the pipe, Mr. King. I speak not from a practical point of view so much as from the point of view of my own experience since Mr. Finneran and the others have started this method. I know that where we used to have innumerable complaints of stoppage they are becoming negligible now, for the simple reason that the pipe

can be cleared so quickly and so easily without digging. The practical result from my point of view is an almost entire stopping of complaints, for it is the simplest thing in the world now to clean a pipe. How long a pipe have you cleaned, Mr. Finneran?

MR. FINNERAN. About 50 ft. is the longest.

MR. GEORGE A. STACY. I should say that this experiment, or this fact, can be easily demonstrated by anybody who is afraid to try it underground by taking some pipe that he has taken out and demonstrate to himself in the shop the actual working of this operation. When a man who is a practical man, engaged in practical work, comes here and says he does this thing and knows that it is so, I believe that there is something in it, — certainly as much as if he had got the information in Germany or at some school. I hope, Mr. President, that we will have more of this sort of thing, for it will seem like old times when we get back to it.

MR. COGGESHALL. I heard the other day that Mr. Finneran has contrived an apparatus whereby he can take his automobile to where there is a large gate, and by rigging up the automobile in some way he can use its power to open or shut the gate. I think that is a pretty good thing, and I would like to know more about it. I think I shall send my master mechanic up to his shop to look into it.

THE PRESIDENT. I might say, Mr. Coggeshall, that that is our method of opening and shutting large gates. I do not want to use all our thunder at once, but that will be described fully in the near future.

THE PRESIDENT. I might say one thing in the line of Mr. Stacy's remark that he hopes there will be more of this sort of thing, and that is that I want to notify the men here to-day, who are in touch all day long with these practical matters, that we expect to hear from them, and that we are going to try very hard to get them to speak to us, because I seriously and honestly believe that there is a very great deal of value which we have lost in the last few years in not following up this idea more and getting this information out.

MR. F. F. FORBES. I would like to inquire where you can purchase this pump? It must be a special pump to get a thousand pounds pressure.

MR. FINNERAN. We had a pump made by the Blake Pump Company. It is not an ordinary pump; you cannot go into the market and buy it. It is a specially made pump. We used it for years in our machine shop, testing large valves that we make up to 24 in. It is a high-powered pump. The water space is very small, it will not pump much water, but it will pump it at a great pressure.

THE PRESIDENT. I think that there should be a gage attached between the pump and the pipe. We have depended up to date on the experience of the men in judging about what the pipes will stand, and they have never yet burst a pipe, but theoretically, certainly, there should be a gage.

MR. SHERMAN. Is it an expensive pump?

MR. FINNERAN. About fifty dollars. We had six made, which cost us three hundred dollars. We made a price with the makers. It is a well-made pump, and it will last indefinitely. There is no wear to it.

MR. FULLER. I would like to know if an ordinary boiler testing pump, which throws a very small amount of water but under, perhaps, 200 lb. pressure, and costing, perhaps, fifteen dollars, would not answer the purpose.

THE PRESIDENT. I have no doubt but that it would. There is no doubt but that a pump entirely satisfactory can be bought for very much less money than we paid.

MR. COGGESHALL. I should like to say that that is just precisely what we use in our department, — an ordinary boiler testing pump; and while we haven't got quite so good results, perhaps, as Mr. Finneran has obtained, it has done us mighty good service in cleaning out service pipes when the ground was frozen, and where we had to do something to augment the supply.

MR. PATRICK GEAR.* A meeting like this, where anybody can talk on any matter he has a mind to, will give one an idea of the troubles somebody else has and how he overcomes them.

I have had that sort of pump for years, and am going to try this experiment when I get home. We have used this pump when we were notified that the water had suddenly been shut off in some building and we had a notion that the service pipe was ob-

* Superintendent of Water Works, Holyoke, Mass.

structed by fish. We would hitch this pump on to the service in the cellar and have a gage on it so we would not get our pressure too high and break anything. We would then shut a gate in the street, open a hydrant, apply the pressure and would generally get an eel through the hydrant. Our first attempts to free services in this manner were made without opening a hydrant, and, while we were successful in removing the obstruction from the service in question, we would get into trouble in some service farther along. By opening the hydrant we had no more trouble and have removed eels two or three feet long. We have never had any idea, however, that the use of this pump would clear out the service pipes of anything but large obstructions of this kind, and I feel well paid for coming down here to-day and learning that it will.

We all know that there is probably no class of men who carry more in their heads than water-works men, and all of us who are connected with water-works departments know that there is no class of engineers who are more expert or specialized in their business than water-works engineers. We have had as our President one of the most eminent engineers in the country, who has just successfully completed one of the biggest engineering jobs in the world, compared to which, so far as engineering skill is concerned, the construction of the Panama Canal was very simple, and yet we did not think anything at all about it.

THE PRESIDENT. I would say to Mr. Gear that I feel confident that he will find that it has paid him to come here. We in Boston for many years have been using a force pump for cleaning services, but we look upon this wad of paper in connection with the force pump as a discovery, so far ahead of the old force-pump method that there is no comparison at all.

ARE TRENCHING MACHINES WORTH CONSIDERING IN EXCAVATING TRENCHES IN CITY STREETS?

TOPICAL DISCUSSION.

[*January 14, 1914.*]

THE PRESIDENT. I don't know whether any one has had any experience in trying to use trenching machines in city streets, but there are a good many engineers present here this afternoon, and some of them should have had experience on this subject and should have something to say.

MR. HARRISON P. EDDY.* It is a pretty broad subject, Mr. President, and there are so many things which can be said about trenching machines that I hardly know where to begin. Of course there is no question but that some type of trenching machine is very desirable in digging many earth trenches. Most water pipes, however, are laid pretty close to the surface, so that the quantity of earth to be moved is relatively small.

The Carson trenching machine, of course, is one of the types which is very familiar in this part of the country, and is of very great assistance in narrow streets, where the trenches are deep and wide. This applies more particularly to sewer trenches perhaps, for which I think the machine was originally designed, although there is no reason why it is not applicable to water trenching under some, although rather exceptional, conditions. This type of trench machine is ordinarily confined to a length of about 300 ft., so that it is not practicable to lay long lengths of pipe at one time, as is usually done. Under some conditions, the use of this type of machine may be very desirable as making it possible to avoid throwing the dirt out on to one side of and blocking the street. Many times it is possible in this way to keep the street open to traffic, whereas if the earth were thrown out as usual, the street could hardly be kept open.

The types of trenching machine which are more commonly

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

used in the Middle West, where the excavating is done by some sort of a bucket elevator, are not often adapted to work in our eastern city streets, on account of the cross pipes encountered and the bracing which is required where the ground has been dug up over and over again. That machine is good for use in earth where the banks remain in position without sheeting and bracing, and where it can proceed without interfering with pipes crossing the trench.

The advantage of some types of machine, like the Carson machine, is that the earth is handled only once, simply being shoveled into a bucket, raised and carried back and dumped on to the completed work. There is, however, as I have said, great difficulty in handling water-pipe work in that way. The types of machines that are used for excavating by means of the bucket elevator in moderately compact or tenacious material can be worked very cheaply, as in many cases the earth is thrown out on to the side of the street and then it is hauled back by means of scrapers. That scheme is used a good deal in the Middle West, where the material is of a loamy nature and is not subject to caving.

MR. FRANK L. FULLER.* Mr. President, I have had two water-works jobs the past summer, one with about 60 cu. yd. of rock excavation in about six miles of trenching; the other with 488 cu. yd. in about 2½ miles. Where there is as much rock as there was in the second case, trenching machines would not be practicable, I think. It seems to me that in New England there is too much rock to permit any saving in making the excavation by machinery, and that getting the material out by pick and shovel will be the cheaper way.

MR. C. E. DAVIS.† In laying about six miles of 12- and 16-in. water pipe in Philadelphia, a Buckeye trenching machine has been used successfully. This machine consists essentially of a large wheel with excavating buckets on the periphery. A conveyer belt carries the earth forward and deposits it to one side of the trench. In Philadelphia it is working successfully in material which is comparatively free from bowlders and of rather a tenacious and clayey nature. Backfilling is being done by hand.

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* Civil Engineer, Boston, Mass.

† Chief Engineer, Bureau of Water, Philadelphia, Pa.

PROCEEDINGS.

Annual Meeting.

Hotel Brunswick,
Boston, Mass., January 14, 1914.

The President, J. Waldo Smith, occupied the chair.
The following members and guests were present:

Honorary Member.

Frederic P. Stearns.

Members.

J. M. Anderson, L. M. Bancroft, F. A. Barbour, H. K. Barrows, Dexter Brackett, E. C. Brooks, James Burnie, G. A. Carpenter, J. C. Chase, J. H. Child, J. E. Conley, A. W. Cuddeback, C. E. Davis, John Doyle, L. R. Dunn, E. R. Dyer, H. P. Eddy, E. D. Eldredge, J. W. Ellis, F. L. Fuller, Patrick Gear, F. J. Gifford, A. S. Glover, J. M. Gooding, F. W. Gow, F. M. Griswold, R. A. Hale, R. K. Hale, F. E. Hall, J. O. Hall, M. F. Hicks, J. L. Howard, A. C. Howes, F. T. Kemble, Willard Kent, J. J. Kirkpatrick, C. F. Knowlton, H. O. Lacount, E. J. Lonergan, Daniel MacDonald, F. E. McInnes, J. N. McKernan, F. E. Merrill, H. A. Miller, F. L. Northrop, S. H. Pitcher, P. R. Sanders, W. J. Sando, J. E. Sheldon, C. W. Sherman, J. W. Smith, G. H. Snell, W. F. Sullivan, R. J. Thomas, L. D. Thorpe, J. L. Tighe, C. H. Tuttle, F. E. Tupper, J. H. Walsh, R. S. Weston, T. H. Wiggin, I. S. Wood, L. C. Wright. — 63.

Associates.

Builders Iron Foundry, by A. B. Coulters; Chapman Valve Manufacturing Company, by J. J. Hartigan and J. F. Mulgrew; *Engineering Record*, by I. S. Holbrook; Hersey Manufacturing Company, by A. S. Glover and W. A. Hersey; Kennedy Valve Company, by M. J. Brosman; Lead-Lined Iron Pipe Company, by T. W. Dwyer; Ludlow Valve Manufacturing Company, by A. R. Taylor and G. A. Miller; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by H. L. Weston; Neptune Meter Company, by H. H. Kinsey; Rensselaer Valve Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. L. Northrop; Standard Cast-Iron Pipe and Foundry Company, by W. F. Woodburn; Thomson

Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall; Water Works Equipment Company, by W. H. Van Winkle, Jr.; R. D. Wood & Co., by H. M. Simons; Henry R. Worthington, by Samuel Harrison. — 21.

GUESTS.

Mr. Joseph A. Hoy, Worcester, Mass.; Charles W. Kinney and Albert H. Tillson, Northampton, Mass., F. M. Bates and C. DeWitt Webb, Boston, Mass.; D. J. Higgins, Waltham, Mass.; F. I. Hall, Middletown, Conn.; C. T. Hall, Malden, Mass., and J. H. Carmichael, Lowell, Mass. — 9.

The Secretary presented applications for active membership, properly endorsed and recommended by the Executive Committee, from Rufus M. Whittet, Boston, Mass., assistant engineer Massachusetts State Board of Health; C. C. Covert, Albany, N. Y., district engineer United States Geological Survey, Water Resources for New York and New England; Joseph A. Hoy, Worcester, Mass., foreman of construction works and service pipes in streets; Charles W. Kinney, Northampton, Mass., president Northampton Water Works; Albert H. Tillson, Northampton, Mass., supervisor of water works; Robert R. Livingston, N. Y., engaged in hydro-electric engineering and construction; and for associate membership, Daniel J. Higgins, Waltham, Mass., manufacturer of steam pumps and valves.

On motion of Mr. Frank L. Fuller, the Secretary was instructed to cast the ballot of the Association in favor of the applicants, and he having done so they were declared duly elected members of the Association.

The Secretary, Mr. Willard Kent, then presented his annual report, as follows:

REPORT OF THE SECRETARY.

NARRAGANSETT PIER, R. I., January 1, 1914.

Mr. President and Gentlemen of the New England Water Works Association,— The Secretary submits herewith the following detailed statement of the changes in membership for the past year.

The present membership is	758
That of one year ago was	731
A gain for the year of	27

Your constitution specifies that the membership shall consist of members, honorary members, and associates.

In the list of honorary members there has been no change, the present number being 12, the same as that of one year ago.

The changes in the list of members and associates are as follows:

MEMBERSHIP.

January 1, 1914.	Honorary members				12
January 1, 1913.	Total members		666		
	Withdrawals:				
	Resigned	17			
	Dropped	27			
	Died	7			
		—	51		
			—	615	
	Initiations:				
	January	6			
	February	1			
	March	10			
	June	5			
	September	19			
	November	5			
	December	5			
		—	51		
	Members elected in 1912, but qualified in 1913		2		
	Reinstated:				
	Member dropped, '10	1			
	Member resigned, '10	1			
	Member dropped, '12	1			
	Members dropped, '13	15			
		—	18	71	
			—	—	686
January 1, 1913.	Total associates	53			
	Withdrawals:				
	Dropped	1	1		
		—		52	
	Initiations:				
	September			8	
				—	60
January 1, 1914.	Total membership				758

Year.	President.	Membership at End of Year.				Annual Convention.		Receipts.	Expenditures.	Cash Balance.
		Members.	Associate.	Honorary.	Total.	Place.	Date.			
1882	(Organized)	27	—	—	27	Boston, Mass.	June 21, '82			
1882–3	*James W. Lyon	37	6	—	43	Worcester, Mass.	June 21, '83	$245.00	$87.86	$157.14
1883–4	Frank E. Hall	48	9	—	57	Lowell, Mass.	June 19–20, '84	156.14	171.90	141.38
1884–5	*George A. Ellis	83	44	—	127	Springfield, Mass.	June 18–19, '85	651.84	511.44	281.78
1885–6	*R. C. P. Coggeshall	106	47	—	153	New Bedford, Mass.	June 16–18, '86	1 658.50	1 643.42	296.86
1886–7	*Henry W. Rogers	137	52	2	191	Manchester, N. H.	June 15–17, '87	1 342.28	1 066.98	572.16
1887–8	*Edwin Darling	181	54	3	238	Providence, R. I.	June 13–15, '88	2 013.30	1 697.15	888.31
1888–9	*Hiram Nevons	209	64	4	277	Fall River, Mass.	June 12–14, '89	2 204.07	2 127.70	964.68
1889–90	Dexter Brackett	257	73	5	335	Portland, Me.	June 11–13, '90	2 511.27	2 346.65	1 129.30
1890–1	*Albert F. Noyes	281	74	5	360	Hartford, Conn.	June 10–12, '91	3 055.13	1 884.78	2 299.65
1891–2	Horace G. Holden	290	70	5	365	Holyoke, Mass.	June 8–10, '92	2 887.17	3 278.54	1 908.28
1892–3	*George F. Chace	338	69	5	412	Worcester, Mass.	June 14–16, '93	3 422.61	3 317.22	2 013.67
1893–4	*Geo. E. Batchelder	365	73	5	443	Boston, Mass.	June 14–16, '94	3 208.85	3 259.07	1 963.45
1894–5	George A. Stacy	401	81	5	487	Burlington, Vt.	Sept. 11–13, '95	3 147.41	3 115.99	2 673.03
1895–6	Desmond FitzGerald	442	82	5	529	Lynn, Mass.	June 10–12, '96	3 179.91	3 148.49	2 704.45
1896–7	*John C. Haskell	464	80	5	549	Newport, R. I.	Sept. 8–10, '97	3 340.23	3 322.94	2 271.74
1897–8	Willard Kent	488	77	5	570	Portsmouth, N. H.	Sept. 14–16, '98	3 002.13	2 786.95	2 936.92
1898–9	Fayette F. Forbes	494	73	5	572	Syracuse, N. Y.	Sept. 13–15, '99	2 825.71	3 050.23	2 712.40
1899–1900	Byron I. Cook	519	70	5	594	Rutland, Vt.	Sept. 19–20, '00	4 920.49	5 524.65	2 108.24
1901	Frank H. Crandall	493	58	4	555	Portland, Me.	Sept. 18–20, '01	4 238.55	4 283.22	2 063.57
1902	Frank E. Merrill	522	60	5	587	Boston, Mass.	Sept. 10–12, '02	5 158.48	4 680.32	2 541.73
1903	*Charles K. Walker	520	55	3	586	Montreal, Canada	Sept. 9–11, '03	5 032.40	4 505.08	3 069.05
1904	Edwin C. Brooks	538	58	8	604	Holyoke, Mass.	Sept. 14–16, '04	5 328.31	5 528.21	2 869.15
1905	George Bowers	584	53	8	645	New York, N. Y.	Sept. 13–16, '05	5 431.16	5 411.58	2 888.73
1906	Wm. T. Sedgwick	618	51	15	684	White Mts., N. H.	Sept. 12–14, '06	5 366.94	4 845.14	3 410.53
1907	John C. Whitney	636	51	15	692	Springfield, Mass.	Sept. 11–13, '07	5 291.83	†4 222.06	4 480.30
1908	Alfred E. Martin	633	49	14	696	Atlantic City, N. J.	Sept. 23–25, '08	5 706.36	7 475.56	‡2 711.10
1909	Robert J. Thomas	647	55	13	715	New York, N. Y.	Sept. 8–10, '09	5 305.31	†4 566.84	‡3 449.57
1910	George A. King	678	56	13	747	Rochester, N. Y.	Sept. 21–23, '10	6 507.08	†7 237.60	‡2 719.05
1911	Allen Hazen	680	58	12	750	Gloucester, Mass.	Sept. 13–15, '11	6 440.90	†6 279.72	‡2 880.23
1912	Geo. W. Batchelder	666	53	12	731	Washington, D. C.	Sept. 18–20, '12	6 861.65	†5 934.56	‡3 807.32
1913	J. Waldo Smith	686	60	12	758	Philadelphia, Pa.	Sept. 10–12, '13	6 122.81	†6 533.62	‡3 396.51

* Deceased. † Not including December JOURNAL and Reprints. ‡ Does not include $1 815 invested in bonds.

The Secretary has received and paid to the Treasurer			$5 909.18
Of this amount the			
Receipts for initiation fees were			$281.00
From dues of members	$2 037.00		
" " " " fractional	38.00		
" " " " part	9.50		
		$2 084.50	
From dues of associates	$770.00		
" " " " fractional	61.25	831.25	
Total from dues			2 915.75
From advertising			1 371.25
" subscriptions			258.00
" JOURNALS			148.50
" sundries			934.68
Total as above			$5 909.18
There is due the Association at this date —			
For advertising			$422.50
" JOURNALS			54.50
Total amount due			$477.00

The outstanding bills against the Association amount to $876.53.

Respectfully submitted,

WILLARD KENT, *Secretary.*

On motion of Mr. Frederic P. Stearns, it was voted that the report of the Secretary be received and placed on file.

The Treasurer, Mr. Lewis M. Bancroft, submitted the following report:

CLASSIFICATION OF RECEIPTS AND EXPENDITURES.

Receipts.

Dividends and interest		$221.01
Initiation fees	$281.00	
Dues	2 915.75	
Total received from members		3 196.75
Amount carried forward		$3 417.76

Amount brought forward		$3 417.76
JOURNAL:		
Advertisements	$1 371.25	
Subscriptions	258.00	
Sale of JOURNALS	148.50	
Sale of Reprints	31.50	
Total received from JOURNAL		1 809.25
Miscellaneous receipts:		
Sale of " Pipe Specifications "	$31.30	
Dinners	670.50	
June excursion	194.00	
Total miscellaneous receipts		895.80
Total receipts		$6 122.81

Expenditures.

JOURNAL:		
Advertising agent, commission	$242.00	
Plates	318.12	
Printing	1 638.30	
Editor's salary	300.00	
Expense	37.36	
Reporting	141.00	
Advance reports	168.71	
Reprints	190.25	
Envelopes	57.00	
		$3 092.74
Office:		
Secretary, salary	$200.00	
Expense	32.50	
Assistant Secretary, salary	600.00	
Expense	164.55	
Rent	300.00	
Printing	116.00	
Stationery	48.00	
Membership lists	199.00	
Envelopes and postage	123.04	
Typewriter	95.00	
Library	13.55	
Miscellaneous	20.50	
		1 912.14
Amount carried forward		$5 004.88

Amount brought forward			$5 004.88
Meetings and Committees:			
Stereopticon		$71.50	
Dinners	$689.00		
Cigars	48.50		
Music	79.00		
		816.50	
Badges		78.14	
Printing and postage		150.35	
			1 116.49
Treasurer's salary and bond			67.50
June excursion			317.25
Printing Pipe Specifications			27.50
			$6 533.62

LEWIS M. BANCROFT, TREASURER,

In account with the New England Water Works Association.

RECEIPTS.			EXPENDITURES.		
1913.					
Jan. 1.	Balance on hand	$3 807.32	Bills paid		$6 533.62
	Received of Willard Kent, Sec'y	5 909.18	BALANCE ON HAND.		
	Interest on bonds and deposits	213.63	People's Savings Bank	$2 000.00	
			Mechanics Savings Bank	1 055.96	
			First National Bank	292.83	
			Liberty Trust Co	47.72	
					3 396.51
		$9 930.13			$9 930.13

ASSETS AND LIABILITIES.

ASSETS.			LIABILITIES.		
Cash, balance in banks		$3 396.51	Accounts payable:		
Bonds Nos. 2642 and 2644 Lake Shore & Mich. So. R. R. 4%, due May 1, 1931. Book value, $1 815. Market value		1 800.00	Rent		$100.00
			Reporting		26.25
			Miscellaneous Printing		81.13
Accounts receivable:			Printing		655.40
JOURNALS	$55.50		Asst. Sec'y, Expense		13.75
Advertising	422.50				$876.53
		478.00	Surplus		4 797.98
		$5 674.51			$5 674.51

READING, January 8, 1914.

LEWIS M. BANCROFT, *Treasurer.*

On motion of Mr. Edwin C. Brooks, it was voted that the report of the Treasurer be accepted and placed on file.

The Editor, Mr. Richard K. Hale, submitted the following report:

Report of the Editor.

Boston, January 14, 1914.

To the New England Water Works Association, — I present the following report for the Journal of the New England Water Works Association for the year 1913.

The accompanying tabulated statements show in detail the amount of material in the Journal; the receipts and expenditures on account of the Journal for the past year (including the cost of the December Journal and reprints, bills for which were received too late to pay in 1913, and which are consequently not included in the Treasurer's statement); and a comparison with the conditions of preceding years.

Size of Volume. — The volume is somewhat larger than in previous years.

Illustrations. — The total cost of illustrations for the year, including printing, has been $491.95, or 13.7 per cent. of the gross cost of the volume.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge, and additional reprints, when desired, at the cost of the paper and press work. The net cost to the Association for reprints has been $105.10. There have been advance copies of seven (7) papers prepared during the year, at a cost of $141.71.

Circulation. — The present circulation of the Journal is:

Members, all grades	758
Subscribers	73
Exchanges	27
Total	858

an increase of 32 over the preceding year. Journals have also been sent to 40 advertisers.

Advertisements. — There has been an average of 25 pages of paid advertising, with an income of $1,690, a slight decrease over last year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $31.30 have been sold; 500 were printed at a cost of $27.50. The net gain up to a year ago had been $254.95, so that the total net gain from this source to date is $258.75. There are still about 400 copies of specifications on hand, or about $40.00 worth if sold at retail.

The Association has a credit of $2.41 at the Boston Post-Office, being the balance of the money deposited for payment of postage upon the Journal at pound rates.

There are no outstanding bills, on account of the Journal, which are not included in these tables.

Respectfully submitted,

RICHARD K. HALE, *Editor.*

TABLE No. 1.

STATEMENT OF MATERIAL IN VOLUME XXVII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1913.

Number.	Date.	Pages of									Total Cuts.
		Papers.	Proceedings.	Total Text.	Membership Changes and Exchange List.	Index.	Advertisements.	Cover and Contents.	Insgt. Plates.	Total.	
1	March	143	25	168	1	—	30	4	9	212	36
2	June	125	13	138	—	—	29	4	6	177	24
3	September	147	16	163	4	—	29	4	17	217	40
4	December	81	4	85	—	6	29	4	3	127	18
	Total	496	58	554	5	6	117	16	35	733	118

TABLE No. 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XXVII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1913.

Receipts.		*Expenditures.*	
Advertisements	$1 690.00	Printing JOURNAL	$1 994.35
Sale of JOURNAL	203.00	Printing illustrations	228.00
Sale of reprints	109.15	Preparing illustrations	263.95
Sale of cuts	3.24	Editor's salary	300.00
Subscriptions	258.00	Editor's incidentals	38.28
	$2 263.39	Advertising agent's commissions	237.00
Net cost of JOURNAL	1 322.90	Miscellaneous printing	1.50
		Reporting	167.25
		Reprints	214.25
		Advance copies	141.71
	$3,586.29		$3 586.29

TABLE No. 3.

COMPARISON BETWEEN VOLUMES XVIII TO XXVII, INCLUSIVE, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

	VOL. XVIII. 1904.	VOL. XIX. 1905.	VOL. XX. 1906.	VOL. XXI. 1907.	VOL. XXII. 1908.	VOL. XXIII. 1909.	VOL. XXIV. 1910.	VOL. XXV. 1911.	VOL. XXVI. 1912.	VOL. XXVII. 1913.
Average edition (copies printed)	900	900	900	1 085	1 000	1 000	1 150	1 000	1 000	1 000
Average membership	596	625	665	693	699	710	732	752	740	745
Circulation at end of year	667	705	767	785	780	802	827	840	826	858
Pages of text	491	587	495	500	500	459	643	475	401	554
Pages of text per 1 000 members	824	939	745	722	715	646	880	632	542	746
Total pages, all kinds	794	784	662	669	681	627	808	654	567	733
Total pages per 1 000 members	1 332	1 254	995	964	976	884	1 090	870	766	984
GROSS COST:										
Total	$2 928.77	$3 266.65	$2 573.61	$2 643.42	$2 733.61	$3 111.15	$3 490.81	$2 625.87	$2 476.55	$3 586.29
Per page	3.69	4.17	3.88	3.95	4.01	4.97	4.32	4.02	4.37	4.89
Per member	4.91	5.23	3.87	3.82	3.91	4.39	4.78	3.50	3.35	4.81
Per member per 1 000 pages	6.18	6.67	5.85	5.70	5.88	7.00	5.90	4.09	5.90	6.46
Per member per 1 000 pp. text	10.00	8.91	7.81	7.62	8.02	9.56	7.44	7.36	8.35	8.68
NET COST:										
Total	$648.11	$1 072.95	$387.96	$483.15	$131.06	$789.98	$1 334.06	$352.82	$98.81	$1 322.90
Per page	.82	1.37	.58	.72	.19	1.26	1.65	.54	.17	1.80
Per member	1.09	1.72	.58	.70	.19	1.11	1.82	.47	.13	1.78
Per member per 1 000 pages	1.30	2.20	.88	1.04	.28	1.78	2.25	.55	.23	2.42
Per member per 1 000 pp. text	2.22	2.93	1.18	1.39	.39	2.43	2.83	.98	.33	2.38

No objection being made, the President announced that the report of the Editor would be received, placed on file and printed in the JOURNAL.

REPORT OF THE AUDITING COMMITTEE.

Mr. John C. Chase submitted the following report of the Auditing Committee:

BOSTON, MASS., January 8, 1914.

We have examined the accounts of the Secretary and Treasurer of the New England Water Works Association, and find the books correctly kept and the various expenditures of the past year supported by duly approved vouchers.

Respectfully submitted,

ALBERT L. SAWYER,
JOHN C. CHASE,
Auditing Committee.

No objection being made, the President announced that the report would be received, placed on file, and printed in the JOURNAL.

REPORT OF COMMITTEE TO PREPARE A STANDARD SPECIFICATION FOR FIRE HYDRANTS.

Mr. H. O. Lacount for the committee "to prepare a standard specification for fire hydrants," presented the following report:

TO THE NEW ENGLAND WATER WORKS ASSOCIATION:

Gentlemen,—Since the last report of your committee a joint conference has been held with representatives of the hydrant manufacturers and the hydrant committees of the American Water Works Association and the National Fire Protection Association. While the conference was unable to come to an agreement on some points, there were a number of items regarding which satisfactory conclusions were reached, and these have been incorporated in the latest revision of the specifications.

The final report of the committee is practically ready, and if agreeable to the Association it will be presented at the next meeting, in February. It is expected that, as usual, advance copies of the proposed specifications will be circulated to the members prior to the meeting, in order to facilitate the discussion when the subject comes before the Association for final consideration.

(Signed) H. O. LACOUNT,
Chairman.

The President announced that the committee would be continued and would make a final report at a later date.

The next matter on the program was the report of the committee "to look after and keep track of legislation and other matters pertaining to the conservation, development, and utilization of the natural resources of the country."

No one being present to represent the committee, the matter was passed.

Mr. Frederic P. Stearns, chairman of the committee "to collect information as to low-water yields of catchment areas in New England, and at their discretion, outside of New England," reported that the committee has made substantial progress, and although not ready at present to report, it hopes to be at an early date.

Report of Committee on Meter Rates.

The Secretary, Mr. Kent, read the following letter from Mr. Allen Hazen, chairman of the Committee on Meter Rates.

December 22, 1913.

Mr. Willard Kent,

Secretary, New England Water Works Association,

Tremont Temple, Boston, Mass.

Dear Sir, — The Committee on Meter Rates respectfully reports that it has held one full meeting, that matters referred to it have been considered by its members, that data are being obtained from members of the Association as to some matters upon which the Committee desired assistance, and that the matter will be further considered during the coming year.

Respectfully,

(Signed) Allen Hazen,
Chairman of Committee.

The President. If there is no objection the committee will be continued.

Report of Committee on Statistics of Water Purification Plants.

Mr. Robert S. Weston. Professor Whipple, being unable to be present to-day, has asked me to report for the Committee on Statistics of Water Purification Plants. The committee has held

two meetings in New York, and has prepared a large number of forms which are being sent out in sets to fifty different water purification plants in the country, with the request that the forms be criticised and the data requested on the forms be sent in to the committee. The committee had hoped to have these forms printed for distribution, but upon further consideration it was thought that it would be wiser to have them perfected before doing so; and your committee hopes to do this at a later meeting of the Association. The work is going to be rather laborious and will require a great deal of correspondence and considerable thought, and your committee asks to be continued.

THE PRESIDENT. If there is no objection, the committee will be continued and report at a later date.

REPORT OF COMMITTEE TO SECURE LEGISLATION TO MAKE WATER BILLS A LIEN ON PROPERTY.*

MR. JOHN O. HALL. *Mr. President and Gentlemen of the Association,* — In conference with Judge Corbett, of the Law Department of the City of Boston, a bill has been prepared, and he will introduce it in the legislature in season for action by the proper committee. I have sent out about seventy requests to various water companies, asking for a statement of their total revenue for the year and the amount lost by reason of change of tenants. Those reports are coming to me; I have at the present time about forty. I have seen the secretary of the Massachusetts Real Estate Exchange and have arranged to have a meeting of our committee with the legislative committee of the Exchange, as soon as the bill is presented to the legislature. We will then thresh the matter out with them and listen to their objections, and I think that without any question we can present the matter in such shape to them that they will assist us in favoring the bill before the committee.

Mr. McInnes is present to-day and he can doubtless inform the Association that the bill will be presented to the legislature in due season, and then I will call the committee together and we will confer on the information which has been secured and

* See also pp. 101, 105.

plan out our action before the legislative committee, and at a later meeting will make a final report of the result.

THE PRESIDENT. If there is no objection the committee will be continued.

REPORT OF COMMITTEE FOR STANDARD SPECIFICATION FOR CAST-IRON PIPE.

MR. F. A. MCINNES. This committee is unable to make other than a progress report at the present time. Undoubtedly we seem to be going slowly, but we feel that it is necessary to do so in order to get what we are aiming at, namely, a specification that will be a distinct advance and one which will be accepted by the great majority of those interested. One meeting has already been held this winter and one is scheduled for to-night, and next week it is hoped that at least an informal joint meeting will be held with the committee of the American Water Works Association. That, I think, expresses our present standing.

THE PRESIDENT. If there is no objection the committee will be continued. We are glad to hear that progress is being made in this very important matter. We realize, with the chairman of the committee, that delay is worth while if we can get a uniform specification that will be agreed to by most of the water-works interests.

The reports of committees having been received, subjects for topical discussion were taken up. The first was, "Methods used to Locate Hidden Leaks in Underground Pipes, with Special Reference to Pipes whose Exact Location is Unknown." The only member who spoke on this subject was Mr. Patrick Gear, of Holyoke.

The next subject was, "Are Trenching Machines Worth Considering in Excavating Trenches in City Streets?" This was discussed by Mr. Harrison P. Eddy, Mr. Frank L. Fuller, and Mr. C. E. Davis.

Then Mr. Francis T. Kemble brought up the matter of a proper charge for fire protection service. This subject was discussed by Mr. Frank E. Merrill, Mr. Charles H. Tuttle, Mr. H. O. Lacount, Mr. Robert S. Weston, Mr. Charles W. Sherman, Mr.

Patrick Gear, Mr. Robert J. Thomas, Mr. Carleton E. Davis, and Mr. John Doyle.

Mr. J. Waldo Smith, the retiring President, then made his address.

President's Address.

Gentlemen of the New England Water Works Association, — The reports which have just been read by the Secretary, the Treasurer, and the Editor have given in detail the conduct of the business of the Association during the past year. All are of an encouraging nature and show a prosperous and healthful condition. The membership shows a net gain of 27 over last year, which is gratifying, when it is considered that 1912 showed a net loss of 19. Further than this, no comments on these reports seem necessary.

This Association has always been noted for the excellence of the work of its special committees, which is disclosed in reports presented from time to time. Progress reports of four committees have been presented during the past year, as follows: Standard Specifications for Cast-Iron Pipe; Standard Specifications for Fire Hydrants; To Look After and Keep Track of Legislation and Other Matters Pertaining to the Conservation, Development, and Utilization of the Natural Resources of the Country; To Collect Information as to Low Water Yields of Catchment Areas in New England, and, at Their Discretion, Outside of New England. The final report of the Committee on Water Consumption and Statistics relating thereto has also been presented, and it forms a most valuable and important addition to the work done by this Association. During the year two new special committees have been appointed, on meter rates and on uniform methods of reporting operation of filtration plants. Both are important subjects which have long needed attention.

The larger engineering societies and associations of a similar technical nature and having national or even international scope are coming to recognize that their growth in influence and ability to benefit their members must largely be along the lines of recommendations and reports by select committees. Considering its size and territorial limits, the New England Water Works Association can justly claim to have been a leader. Its committees

have been made up of skillful men, experienced in the particular line of research required, who have been willing to sacrifice valuable time and even money in making the necessary studies. The difficulties of committee work arise from the fact that most men, and particularly those who are suitable committee members, are almost constantly busily occupied with their regular duties. A water-works superintendent must be a very versatile man. He must, first of all, be an engineer, using the term in its broad and not in its technical sense. He must also be something of a lawyer, an accountant, a bookkeeper, a resourceful mechanic, and a diplomat, and naturally, as a result, his time is very fully occupied in performing these many functions of his position. The engineer engaged in consulting or construction work has many and varied obligations of which he must acquit himself, and so his time, too, is only to a limited extent his own. When all of these conditions are considered and it is remembered that in nearly every case these excellent reports have been the product of the "midnight oil," this Association is indeed to be congratulated on the high quality of the work which has been performed by its committees.

Even with a high-class committee, successful work is possible only through the cordial coöperation and assistance of the general membership of the Association. The speaker has, himself, experienced great difficulty in gathering definite and reliable information on various subjects. The reports and replies received in response to letters asking for information are most often indefinite and misleading. Thus, for example, the answers to an inquiry concerning the satisfaction which has been given by some automatic device in general use in connection with water supplies will reveal a most astounding condition of affairs. Many will report "perfect performance" and many will say that the device is of absolutely "no use." In this connection the speaker is reminded of the story of the two men who were discussing the laundry question. One complained that he had no end of trouble and the other that he always got perfect service. It developed, however, in discussion, that the "no trouble" man never counted the pieces he sent to be laundered! There are many, in all walks of life, who shut their eyes to trouble in a similar manner, and no

exception can be made of the water-works engineer. The speaker is convinced, from what he has observed, that many devices and appliances used on water systems are accepted on faith and are never put through a practical test to determine their efficiency and reliability in the situations where they are to be used. These devices after installation are seldom examined, and so it is never known whether they perform their intended function either perfectly or not at all. It thus comes to pass that the man who never looks for trouble is the one most likely to make erroneous and misleading reports.

This Association is essentially one of water-works superintendents — hard-headed practical men of good judgment — resourceful and adaptable. To aid them in their work of construction and management of water-works plants have come the engineers. Both classes are necessary for success, and there should be, wherever the best results are to be obtained, the most cordial coöperation. The ability to coöperate must also exist between engineer and contractor, between the superintendent and his men and between the rank and file of the working force. The more perfect the coöperation, the more noiselessly, efficiently, and economically the machine will run. This spirit of working hand in hand for the furtherance of the job is the keynote of the success of every work or enterprise. It is the foundation on which is built the attainment of the best results, in the quickest time and for the least expenditure. Fair dealing, harmony, and honest coöperation do more to oil the wheels of progress than all other known factors and result in the highest credit for the superintendent, for the engineer, for the contractor and for every man on the work. But coöperation and unity of thought cannot be had without some sacrifice on the part of every individual who may be charged with any degree of responsibility. The superintendent must often subordinate his views to those of his foreman, so that they, in turn, may fully understand and share with him the satisfaction and joy of attainment and successful accomplishment. The engineer must often accept the ideas of his inspectors, for, if he does not, whence can their lively and healthful interest in the work be expected to come? It matters little by just what method a thing is done, but it matters much, indeed, that the

thing when done shall be as perfect as possible and properly perform its intended function. All of us are often too prone to stick close to our own ideas and defend them to the bitter end of ignominious failure, and some, even in failure, learn not! The yielding of an immaterial point, or often one which for the moment seems most vital, is one of the surest ways in which coöperation can be induced among individuals and by which unswerving loyalty to a work, to a project, or to a cause can, in the first place, be induced, and, in the second, held immovably fast. But subordination of one's own pet ideas and theories is not of itself all sufficient, unless proper credit is given for that plan which is finally adopted and unless due recognition of individual merit and ability is freely and honestly given.

The financial rewards of those in charge of water-works systems are very small when the great responsibility is considered and when it is remembered that success is to be obtained only as the result of continual vigilance and never-failing fidelity. But it so happens, fortunately indeed, that those endowed with most of this world's goods are not the happiest and that the realization of a duty well performed is of itself the highest of rewards. No greater joy can come to any one than that resulting from his associations and his accomplishments. Both of these are within the reach of every one, and I am sure that by the large majority of you they have already been attained and are among the choicest of your possessions.

In these days of unrest among all classes and conditions of men, and particularly among those high in the councils of our governing political bodies, it is indeed a pleasure, and none the less my duty, to bear witness to the unswerving honesty, fidelity, and loyalty which has as a class always characterized the water-works man and the engineer. It is my earnest hope that they will see their way clear to look beyond their immediate duties and the responsibilities of their environment, and take a greater interest and exert a real and more marked influence on the many and complex problems which our urban development has forced upon us. The man of technical training and possessing all of the qualifications and characteristics which the water-works man must of necessity be endowed with is the one, after all, who is best

fitted to further and progress any work or movement he may undertake. It is necessary only for him to put his shoulder to the wheel and make up his mind to take the same active part in the affairs of his city as that which he has played in the water department. Having once taken the plunge, he will find awaiting him the same measure of success and he will wonder why he was so long content to see the reward and the credit go to others who deserved it less; yes, indeed, to many who deserved it not at all!

But, as we seek to widen our field of activity, let us steadfastly refuse to follow the easy and now popular style of advancement through carping and destructive criticism. All can criticise, but few can raise up; let us be builders and not tearers down! Let us take what may be justly criticised and improve and make the best of it, rather than to uproot it stem and branch, only to cast it down to destruction. Let us take the constructive side and, in so doing, play our part in helping to make this world better, brighter, and more livable. But withal, let us subordinate our desires and ambitions of personal aggrandizement so that whatever we may do and accomplish will pay its own reward in that sense and feeling of satisfaction which ever comes to those who, in doing a good work, do it well.

Let us ever do the tasks which come to us with honesty and with fidelity of purpose, so that wherever or whenever our time of trial may come, we can boldly and without fear look the whole world in the face and bid any and every member of society to come on and do his worst.

Report of Tellers.

The tellers appointed to canvass the ballots for officers for the coming year submitted the following report:

Election of Officers.

Whole number of ballots	275
Blank	9

President.

Frank A. McInnes	262
Scattering	1

Vice-President.

Leonard Metcalf	272	James W. Blackmer	267
William F. Sullivan	268	Charles E. Chandler	265
Carleton E. Davis	267	Scattering	2
Melville A. Sinclair	265		

Secretary.

Willard Kent	273

Treasurer.

Lewis M. Bancroft	268

Editor.

Richard K. Hale	268

Advertising Agent.

George A. King	264
Scattering	1

Additional Members of Executive Committee.

Robert J. Thomas	265
Samuel E. Killam	263
Samuel P. Senior	263
Scattering	1

Finance Committee.

George H. Finneran	263
A. R. Hathaway	265
Frederick W. Gow	271
Scattering	2

Respectfully submitted,

F. M. GRISWOLD.
A. C. HOWES.
S. H. PITCHER.

Mr. J. Waldo Smith. It is now my duty and pleasure to hand over this gavel to my distinguished successor, Mr. McInnes, and to introduce him, if he needs any introduction, to the New England Water Works Association. [*Applause.*]

President McInnes. Gentlemen, this is my first experience at this table, and, if I tell the whole truth, I am at this moment very envious of you gentlemen who are sitting in front of me. However, it is your will and it is my duty, and it shall be my en-

deavor to justify your choice. Your very kind applause was sweet music, for it gives me reason to hope that for the coming year the past high standards of the Association may be maintained, for without your coöperation I fully realize that nothing worth while can be done. I sincerely thank you for the great honor you have done me. [*Applause.*]

Adjourned.

FEBRUARY MEETING.

HOTEL BRUNSWICK,
BOSTON, February 11, 1914.

The President, Mr. Frank A. McInnes, in the chair.

The following members and guests were present:

MEMBERS.

A. F. Ballou, L. M. Bancroft, F. A. Barbour, A. E. Blackmer, J. W. Blackmer, George Bowers, James Burnie, G. A. Carpenter, George Cassell, J. C. Chase, R. D. Chase, R. C. P. Coggeshall, C. H. Eglee, E. D. Eldredge, G. F. Evans, G. H. Finneran, F. F. Forbes, R. V. French, A. D. Fuller, F. L. Fuller, Patrick Gear, A. S. Glover, Clarence Goldsmith, R. A. Hale, R. K. Hale, F. E. Hall, J. O. Hall, L. M. Hastings, A. R. Hathaway, Allen Hazen, D. J. Higgins, H. R. Johnson, W. S. Johnson, E. W. Kent, Willard Kent, G. A. King, F. F. Longley, F. A. McInnes, Thomas McKenzie, W. E. Maybury, John Mayo, H. A. Miller, William Naylor, T. A. Peirce, L. C. Robinson, P. R. Sanders, A. L. Sawyer, C. W. Sherman, G. A. Stacy, W. F. Sullivan, C. N. Taylor, L. D. Thorpe, E. J. Titcomb, D. N. Tower, C. H. Tuttle, F. E. Tupper, A. H. Tillson, W. H. Vaughn, Percy Warren, F. P. Washburn, R. S. Weston, H. L. Whitney, F. B. Wilkins, F. I. Winslow, G. E. Winslow, I. S. Wood, and L. C. Wright. — 68.

ASSOCIATES.

Chapman Valve Manufacturing Company, by H. U. Starr and J. F. Mulgrew; Goulds Manufacturing Company, by R. E. Hall; Joseph Dixon Crucible Company, by H. A. Neally; Hersey Manufacturing Company, by A. S. Glover and W. A. Hersey; Lead Lined Iron Pipe Company, by T. W. Dwyer; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by J. G. Lufkin and H. L. Weston; Neptune Meter Company, by H. H. Kinsey; Norwood Engineering Company, by R. B. Weir; Pitometer Company, by E. D. Case; Pittsburg Meter Company, by J. N. Turner; Pratt & Cady Company, by C. E. Pratt; Rensselaer Valve Company, by C. L. Brown; Standard Cast Iron Pipe and Foundry Company, by W. F. Woodburn; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E.

Hall; Water Works Equipment Company, by W. H. Van Winkle, Jr.; R. D. Wood & Co., by C. R. Wood; Henry R. Worthington by Samuel Harrison, E. P. Howard, and W. F. Bird. — 24.

GUESTS.

C. C. Young, Lawrence, Kan.; Frank F. Street, A. J. Brown, Reading, Mass.; James Kinloch, East Greenwich, R. I.; George W. Bowers, Lowell, Mass.; S. W. Hume, New York; S. L. Hildreth, Manchester, Mass.; C. A. Abbott, Derry, N. H.; Prof. S. C. Prescott, Boston; Joseph Weeks, Bridgewater, Mass.; R. F. Forrest, Randolph, Mass.; E. E. Abercrombie, Beverly, Mass.; E. H. Magoon, Almon L. Fales, Boston, Mass.; H. H. Ambler, T. P. Hsi, Z. Y. Chow, E. W. Bowles, C. J. Callahan, E. D. Hayward, E. C. Taylor, and S. Brack. — 22.

The Secretary presented the application for membership, properly endorsed and recommended by the Executive Committee, of C. C. Young, Lawrence, Kan., director of the Kansas State Water Survey. On motion of Mr. T. A. Peirce, the Secretary was instructed to cast the ballot of the Association in favor of the applicant, and he having done so Mr. Young was declared duly elected an active member of the Association.

The Secretary read the following letter and report from Mr. M. N. Baker, chairman of the committee "to look after and keep track of legislation and other matters pertaining to the conservation, development, and utilization of the natural resources of the country."

NEW YORK, January 13, 1914.

MR. WILLARD KENT,

Secretary, New England Water Works Association,

TREMONT TEMPLE, BOSTON, MASS.

Dear Mr. Kent, — I regret to say that I will be unable to be at the meeting to-morrow. I enclose a "progress" report for the Conservation Committee.

Yours truly,

M. N. BAKER.

Report of Committee to Look After and Keep Track of Legislation and Other Matters pertaining to the Conservation, Development, and Utilization of the Natural Resources of the Country.

The committee as a whole has no report to submit. The chairman begs to suggest that there seems to be little for the committee to do, and that the committee might be discharged without loss to the Association. In case the Association wishes to continue the committee, the chairman respectfully suggests that its long and cumbersone title be changed to read "Committee on Conservation."

Respectfully submitted,

M. N. Baker, *Chairman.*

On motion of Mr. Sherman, it was voted that the report of the committee be accepted and the committee discharged.

Report of Committee to Secure Legislation to Make Water Bills a Lien on Property.*

Mr. John O. Hall. The committee to which was assigned the matter of trying to secure legislation to make unpaid water bills a lien on the estate beg leave to report progress. At the present time we are apparently licked, but we do not propose to stay licked if we can help it. The bills were properly filed, and a hearing was assigned for January 26. Your committee got busy and got out all the notices that they could to various members of the Association. We appeared before the committee, some few of us, and stated our position in regard to the matter, but the committee reported leave to withdraw. That report was accepted on February 5, I think. Now, in connection with the President and Mr. Sullivan, we propose to see if there is not any parliamentary action we can take to revive the situation this year and bring the bill up again.

Mr. Robert Spurr Weston, consulting sanitary engineer, Boston, Mass., presented a paper entitled, "Some Recent Experiences in the Deferrization and Demanganization of Water."

* See also pp. 91, 105.

He prefaced the reading of the paper by numerous experiments illustrating his subject, and at the conclusion of the paper further illustrated his work by a series of lantern slides. The paper was discussed by Mr. F. F. Forbes and Mr. Allen Hazen.

THE PRESIDENT. My ambition, gentlemen, is, as doubtless has been that of all the presidents before me, to make these meetings as interesting as they can possibly be made. Now, one thing which has been borne in on my mind very strongly indeed, is, that the practical men — I mean by that the men who spend all of their time in the actual work of operating water works, practical water-works men — have not been in evidence as much as they should have been, in the last few years, for the best interests of all of us. They were wise enough to found this Association and to bring it to a high plane practically unaided, and I am convinced that they are wise enough now to give the Association a great deal more of value than they have given it in the last few years, since I have been a member. Sometimes very homely things are also very valuable things, and somehow or other I want to see if I can't get you to tell us some of those things, so that we all may know them and may have the advantage of them. So what I have in mind is that we may have something that may be termed a practical half hour, during which the superintendents and managers, the men who all day long work and think in connection with our various problems, can tell us whatever of interest and whatever of value may have occurred to them.

MR. STACY. Mr. President, I want to say a word about another matter. I understand that it is a settled fact, that we are going to have our next annual convention in Boston. That being so, I think it is well for us to consider making a special effort so that it may be the banner convention. Boston is the headquarters of this Association, and there are attractions enough here and in this vicinity to entertain the world, and I hope an effort will be made to make the next annual convention better than any that we have ever had, worthy of the city and worthy of the Association.

MR. W. S. JOHNSON. It may be of interest in connection with what Mr. Stacy has just said to know that during the last winter, when I have been trying to get some statistics with regard to the

small water-works systems in Massachusetts, I have found that out of 113 different towns, only 15 are represented in this society. That is, of 113 water-works systems in Massachusetts, small water-works systems, there are nearly one hundred which have no representative here. Now, it seems to me this is a thing which ought not to be. The superintendent of a small water works needs this Association a good deal more than the superintendent of a large system, and we need him also. I think in many cases the superintendents would be glad to be members of the Association, — I have found it so when I have approached them, — but they haven't had their attention called to us. It seems to me that in connection with the next annual convention would be a good time to get in some of these men who are running the smaller plants.

MR. CALDWELL. Along that line, Mr. President, of getting the superintendents of the small works in, I have talked that a good deal myself when I have come in contact with them, and I have found that the majority of them would like to become members of the Association. But there is one thing that stands in their way, and that is that they are paid such small salaries that they don't feel that they can stand the expense. It seems to me that if this matter could be brought before the water boards and put up to them in the right light, they might be willing to pay the dues for their superintendents to become members of the Association. You can't blame a man who is getting may be fifty dollars a month and having to live on that, for not becoming a member of the Association and having to pay his own expenses. I make this as a suggestion, that you send out a circular letter to the water boards, calling attention to the fact that it would be for their interest more than for the interest of the superintendents themselves, to have them become members of the Association.

THE PRESIDENT. These remarks are particularly interesting to me, because it seems almost self-evident that there never has been a year when it has been so very desirable, in fact almost imperative, that we should largely increase our membership. It seems to be a necessity this year, and I am very glad to have heard the remarks on this line.

Adjourned.

HOTEL BRUNSWICK,
BOSTON, MASS., March 11, 1914.

President Frank A. McInnes in the chair.
The following members and guests were present:

HONORARY MEMBER.

Desmond FitzGerald.

MEMBERS.

A. F. Ballou, L. M. Bancroft, F. A. Barbour, A. E. Blackmer, J. W. Blackmer, E. M. Blake, Dexter Brackett, E. C. Brooks, W. L. Butcher, G. A. Carpenter, F. H. Carter, J. C. Chase, R. D. Chase, J. H. Child, W. R. Conard, J. H. Cook, J. A. Cushman, J. M. Diven, A. O. Doane, E. D. Eldredge, G. F. Evans, F. F. Forbes, E. V. French, F. L. Fuller, Patrick Gear, A. S. Glover, Clarence Goldsmith, J. M. Goodell, F. W. Gow, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, J. O. Hall, H. A. Hanscom, A. R. Hathaway, T. G. Hazard, Jr., D. A. Heffernan, A. C. Howes, H. R. Johnson, W. S. Johnson, E. W. Kent, Willard Kent, Patrick Kieran, G. A. King, Morris Knowles, H. O. Lacount, F. A. McInnes, S. H. McKenzie, Thomas McKenzie, W. A. McKenzie, J. N. McKernan, W. E. Maybury, John Mayo, J. H. Mendell, F. E. Merrill, H. A. Miller, William Naylor, Henry Newhall, F. L. Northrop, R. W. Parlin, T. A. Peirce, H. E. Perry, Dwight Porter, L. C. Robinson, P. R. Sanders, A. L. Sawyer, J. E. Sheldon, C. W. Sherman, Sidney Smith, G. A. Stacy, W. F. Sullivan, H. A. Symonds, H. L. Thomas, R. J. Thomas, L. D. Thorpe, J. A. Tilden, A. H. Tillson, E. J. Titcomb, D. N. Tower, C. H. Tuttle, F. E. Tupper, W. H. Vaughn, G. E. Winslow, I. S. Wood, and L. C. Wright. — 86.

ASSOCIATES.

Allen & Reed, Inc., by Z. M. Jencks; Builders Iron Foundry, by A. B. Coulters; Chapman Valve Manufacturing Company, by J. J. Hartigan, C. E. Pratt, Robert Shirley, J. F. Mulgrew, and A. C. Pilcher; Darling Pump and Manufacturing Company, Limited, by H. A. Snyder and J. L. Hough; Eddy Valve Company, by John Knickerbocker; Hersey Manufacturing Company, by A. S. Glover, J. A. Tilden, and W. A. Hersey; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by J. K. Caldwell and A. R. Taylor; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by J. G. Lufkin and H. L. Weston; National Water Main Cleaning Company, by B. B. Hodgman; Neptune Meter Company, by H. H. Kinsey; Norwood Engineering Company, by H. W. Hosford; Pitometer Company, by E. D. Case; Pittsburgh Meter Company, by J. W. Turner; Rensselaer Valve Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. L. Northrop; Standard Cast-Iron Pipe and Foundry Company, by W. F. Woodburn; Thomson Meter

Company, by S. D. Higley and E. M. Shedd; Union Water Meter Company, by F. E. Hall; United States Cast-Iron Pipe and Foundry Company, by W. G. Sackett; Water Works Equipment Company, by W. H. Van Winkle, Jr.; R. D. Wood & Co., by H. M. Simons; and Henry R. Worthington, by Samuel Harrison and E. P. Howard. — 35.

GUESTS.

John Damon, water commissioner, Plymouth, Mass.; C. B. Parker, Melrose, Mass.; F. S. Lovewell, Providence, R. I.; Z. R. Forbes, water registrar, Brookline, Mass.; Edward Lotz, assistant superintendent, Southington, Conn.; Fred Darling, superintendent water works, Franklin, Mass.; H. A. Rowell, engineer, Concord, N. H.; J. G. Whitman, superintendent water works, Quincy, Mass.; Thos. E. Irwin, New York, N. Y.; R. A. Thayer, engineer, Lockwood Company; J. P. Wentworth, and W. O. Teague, engineer Factory Mutual Company, Boston, Mass. — 12.

The Secretary presented the following applications for membership, properly endorsed and recommended by the Executive Committee: Patrick J. Lucey, Holyoke, Mass., engineer of the Holyoke Water Works; Almon L. Fales, Worcester, Mass., formerly chemist in charge of the laboratories at Worcester City Hall and the sewerage works and superintendent of the works, and now of the firm of Metcalf & Eddy; William H. Butler, Wakefield, Mass., superintendent water works.

On motion of Mr. Thomas A. Pierce, the Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so, they were declared duly elected members of the Association.

Mr. John O. Hall, for the committee on the matter of securing legislation making water bills a lien on real estate, submitted the following report: *

BOSTON, MASS., February 11, 1914.

NEW ENGLAND WATER WORKS ASSOCIATION, in Session:

Mr. President and Gentlemen, — Your committee to whom was assigned the matter of securing legislation making water bills a lien on real estate have attended to that duty and beg leave to report as follows:

A bill, copy of which is attached hereto, was introduced in the legislature, and the matter was presented before the Joint Committee on Judiciary at a hearing on January 26.

On that bill the committee reported "leave to withdraw," and the report

* See also pp. 91, 101, 105.

has been accepted by both the House and Senate, and the matter is killed for this year.

The chairman of your committee interviewed the Senate chairman of the committee and he informed me that they reached their decision on the ground of making extra labor in the examination of conveyances.

He stated to me that the amounts lost in the different cities and towns was very small compared to the amount of the annual water bills.

Your committee received returns from 48 cities and towns. The information contained in those returns is appended hereto.

Respectfully submitted,

JOHN O. HALL,
A. R. HATHAWAY,
GEORGE A. KING,
Committee.

EXHIBIT A.

TABLE SHOWING THE TOTAL COLLECTIONS OF WATER RATES AND THE AMOUNTS UNCOLLECTIBLE.

	Total Collections.	Amount Uncollectible.
Onset	$9 500.00	$308.00
Quincy	122 000.00	734.99
Wellesley Hills	25 598.00	20.70
Manchester	19 420.44	76.15
Gardner	62 688.72	219.04
Gloucester	108 700.00	50.00
Weston	7 000.00	0.00
Marlboro	38 743.30	24.68
Chelsea	124 164.14	682.21
Winchendon	10 001.07	1.33
Haverhill	165 000.00	0.00
Lawrence	14 970.39	599.67
Franklin	17 765.52	.....
Cohasset	18 000.00	15.00
Somerville	232 817.00	118.47
Northampton	54 917.55	47.26
Springfield	375 558.61	50.00
North Andover	11 691.60	0.00
Medford	68 588.68	131.83
Bridgewater	16 000.00	0.00
Ware	11 476.73	.....
Wakefield	.....	2% (I think this is a mistake.)
Holyoke	144 982.00	27.75
Clinton	33 694.71	0.00
Danvers	36 000.00	100.00

	Total Collections.	Amount Uncollectible.
Andover	$22 000.00	.....
Brockton	145 889.42	$95.72
Chicopee	76 595.35	75.00
Worcester	448 366.95	239.75
Milton	36 000.00	50.00
Fitchburg	86 656.46	300.00
Lincoln	12 000.00	.....
Winthrop	40 006.12	221.97
Boston	2 908 500.00	2 000.00
Milford	57 378.96	18.16
Fall River	240 000.00	.....
Watertown	58 032.00	100.00
Newton	14 300.00	500.00
Concord	25 196.49	12.00
Everett	120 000.00	53.75
New Bedford	265 532.77	429.63
Ashland	250 000.00	.....
Hartford, Conn.	383 000.00	.....
Natick	23 000.00	Very small.
Plymouth	46 362.38	Very small; practically nothing.

EXHIBIT B.

HOUSE.....No. 368.

THE COMMONWEALTH OF MASSACHUSETTS.

In the Year One Thousand Nine Hundred and Fourteen.

An Act

To make Unpaid Water Rates Liens on Real Estate.

Be it enacted, etc.

SECTION 1. The owner or owners of real estate shall be liable for the payment of the rate or rates fixed by any city or town for the use of water furnished by such city or town to such real estate or any part thereof; and such rates shall be a lien upon such real estate in like manner as taxes assessed on real estate are liens, and if not paid at the time and as provided by said city or town, shall be collected in like manner to the method of collection of taxes assessed on real estate.

SECTION 2. This act shall take effect upon its passage.

On motion of Mr. George A. Stacy, it was voted that the report be accepted and placed on file.

Mr. William S. Johnson, sanitary and hydraulic engineer, Boston, Mass., then read a paper entitled, "Some Problems Connected with the Design of Small Water-Works Systems." The paper was illustrated by stereopticon views. It was discussed by Mr. Edward V. French, Mr. S. H. McKenzie, Mr. R. D. Chase, Mr. A. R. Hathaway, Mr. Frank L. Fuller, Mr. Henry A. Symonds and Mr. Raymond W. Parlin.

Mr. Joseph N. McKernan, engineer and superintendent, Plainville Water Company, Plainville, Conn., read a paper entitled, "A Study of Rates of the Private Water Companies in Connecticut." The paper was discussed by Mr. S. H. McKenzie and Mr. Raymond W. Parlin.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee at headquarters, Tremont Temple, at 11 o'clock A.M., Wednesday, January 14, 1914.

Present: President J. Waldo Smith, Frank A. McInnes, James L. Tighe, Richard K. Hale, L. M. Bancroft, and Willard Kent.

The following applications for membership were received and by unanimous vote recommended therefor: Rufus M. Whittet, assistant engineer, Massachusetts State Board of Health, Boston, Mass.; C. C. Covert, district engineer, United States Geological Survey, Albany, N. Y.; Joseph A. Hoy, foreman water-works construction work, Worceste , Mass.; Charles W. Kinney, president Water Board, Northampton, Mass.; Albert H. Tillson, supervisor water works, Northampton, Mass.; Robert R. Livingston, hydro-electric engineer, New York, N. Y.; Daniel J. Higgins, superintendent water works, Waltham, Mass.

Voted, that the Editor be and hereby is authorized to prepare a complete index of the JOURNAL of the Association.

Adjourned.

WILLARD KENT, *Secretary*.

Meeting of the Executive Committee of the New England Water Works Association at Hotel Brunswick, Boston, Mass., January 14, 1914, at 4 o'clock P.M.

Present: President Frank A. McInnes, J. Waldo Smith, Carleton E. Davis, William F. Sullivan, Richard K. Hale, Robert J. Thomas, and Willard Kent.

After discussion it was *voted*, that the next annual convention of the Association be held at Boston, Mass., September 9, 10, and 11, 1914, and that the June outing be held at Worcester, Mass., on the second Wednesday of that month.

Adjourned.

WILLARD KENT, *Secretary*.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, February 11, 1914, at 11.30 A.M.

Present: President Frank A. McInnes, William F. Sullivan, James W. Blackmer, Samuel E. Killam, Willard Kent, Richard K. Hale, Lewis M. Bancroft, and George A. King.

Voted, that the President be and hereby is authorized to appoint a committee on papers to be presented to the Association.

Voted, that the President be and hereby is authorized to appoint committees to arrange for the June meeting and the annual convention of the Association.

Application of C. C. Young, director of State Water Survey of Kansas, for membership was received and he was by unanimous vote recommended therefor.

A communication from the National Association of Master Steam and Hot Water Fitters, with reference to a standard schedule for flange fittings, was received and referred to the Committee on Standard Specifications for Cast-Iron Pipe.

Voted, that Editor Richard K. Hale be and hereby is authorized to have prepared a complete index of the JOURNAL of the Association to date.

The Secretary reports the receipt of the renewal certificate of the Treasurer's bond for the ensuing year.

The committee on a certificate of membership presented a design and was by vote authorized and directed to have the design executed and the certificates prepared.

Adjourned.

WILLARD KENT, *Secretary*.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, March 11, 1914, at 11.30 A.M.

Present, President Frank A. McInnes, and members William F. Sullivan, Samuel E. Killam, Richard K. Hale, Lewis M. Bancroft, George A. King, and Willard Kent.

Three applications for membership were presented; viz., Almon L. Fales, of firm of Metcalf & Eddy, consulting engi-

neers, Boston, Mass.; Patrick J. Lucey, engineer Holyoke Water Works, Holyoke, Mass.; William H. Butler, superintendent water works, Wakefield, Mass.

One application for reinstatement was received, and it was unanimously voted that the applicant be and hereby is reinstated to membership on his compliance with the requirements of the Constitution.

Voted, That the President be and hereby is authorized to call an extra meeting of the Association in April at his discretion.

Adjourned.

WILLARD KENT, *Secretary.*